ENERGY CONSERVATION IN THE INDUSTRIAL MINERAL SECTOR – COMMINUTION –

Prepared for:

Canada Center for Mineral and Energy Technology (CANMET)

Energy, Mines and Resources Canada

Volume I

Summary Report – Phase I
Summary Report – Phase II
Pilot Plant Proposal

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VOLUME I
SUMMARY REPORT - Phase 1
SUMMARY REPORT - Phase 11
Pilot plant proposal

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SUMMARY REPORT

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MICROMEDIA

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The experience and active participation of these Companies was invaluable in compiling a realistic set of data.

It is the sincere wish of Canada Cement Lafarge Ltd. that those who took part in the study will benefit from the results.

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Mr. G.W. Riley, Manager, Mineral Processing Laboratory, CANMET - the Project Leader;

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The department of Energy, Mines and Resources (EMR) CANMET, wishing to assist the industrial minerals processing sector in improving the energy efficiency of its operations and to stimulate R&D, commissioned this study.

The overall objective as stated by EMR was,

> to develop the necessary technology to optimize the comminution of industrial minerals in terms of direct and indirect energy consumption.

Ten industrial minerals were chosen for study and, to achieve the objective, the work was divided by EMR into three phases.

Phase I

> Plant studies to develop a data base.

Phase II

> Establishment of particle size monitoring methodology.
>
> Under this phase, a proposal for pilot plant testing was developed.

Phase III

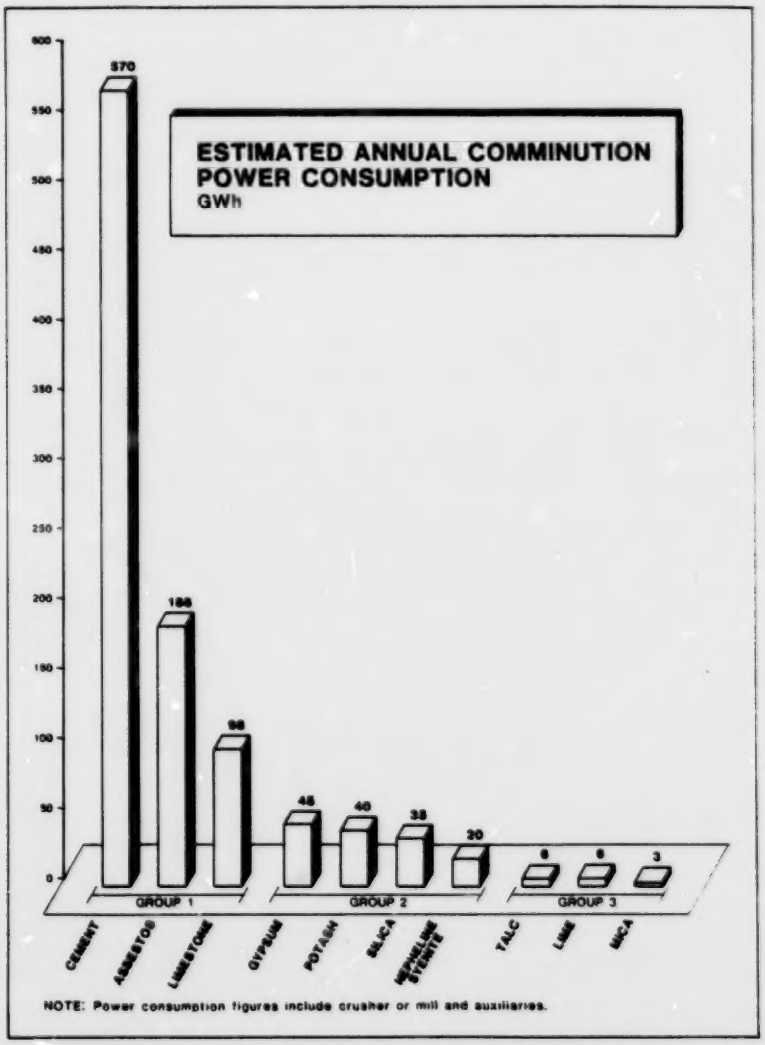
> Development of pilot plant system.
>
> Pilot plant development was not part of the scope of work.

PHASE I PLANT STUDIES TO DEVELOP A DATA BASE

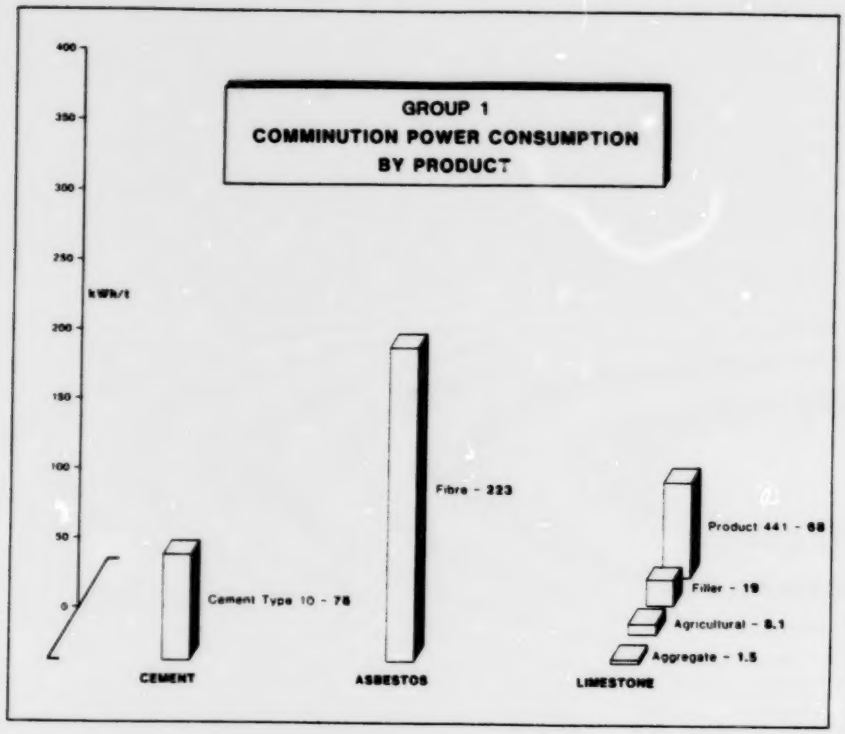
RESULTS

The industries can be ranked into three groups based on estimate of power consumed annually in comminution.

Group 1	Group 2	Group 3
High	Moderate	Low
Cement	Gypsum	Talc
Asbestos	Potash	Lime
Limestone	Silica	Mica
	Nepheline Syenite	



Group 1



Cement

The relatively high specific power consumption and annual tonnages over 7 million account for the high industry power demand.

In the finished product 20-25% of the particles are either too coarse or too fine to contribute to product strength. Thus, improved classification could result in considerable power conservation.

Asbestos

The asbestos industry is different from the other industrial minerals in that:

- large tonnages of ore must be processed to yield relatively small amounts of fibre,

- the role of comminution is to release fibre from the host rock rather than size reduction,

- 45% of the power consumed in comminution circuits is for dust collection.

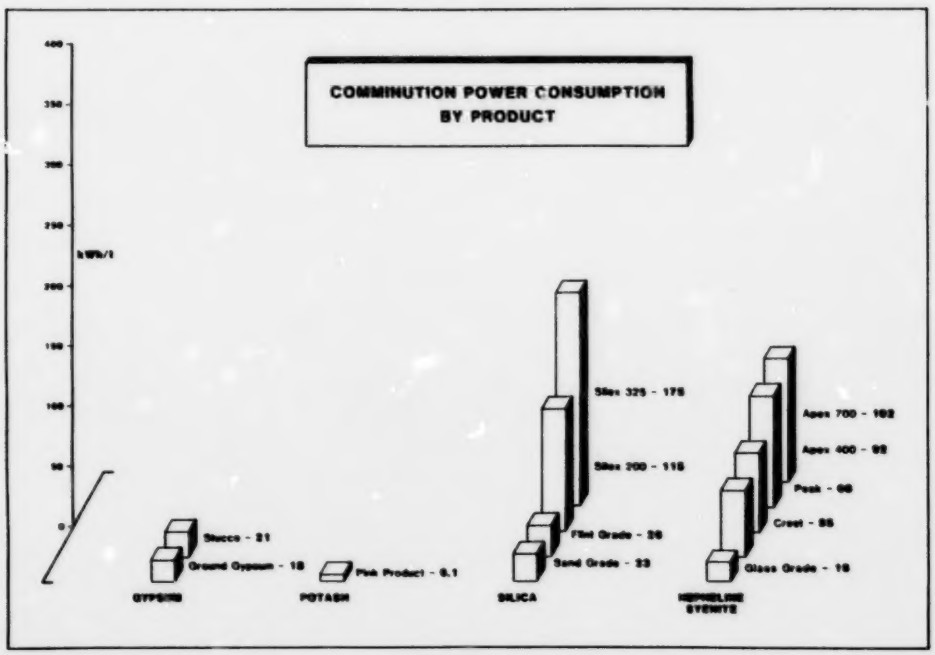
The potential for power conservation is considerable and might be achieved through wet milling.

Limestone

Industry power demand is high because close to 60 million tonnes of limestone are produced annually. Of this, however, 90% is crushed stone which requires less than 2 kWh/t.

The efficiency of the fine grinding operations, particularly at the new installations and the moderate tonnage of the fine products suggest that there is limited scope for conservation.

Group 2



Gypsum

Power consumed in comminution is relatively low compared to other industrial minerals. This can be attributable to the ease of grinding of the material and coarseness of the product.

The scope of conservation appears to be limited.

Potash

The comminution power required per tonne of product is low because there is no fine grinding. Opportunities for power conservation are limited.

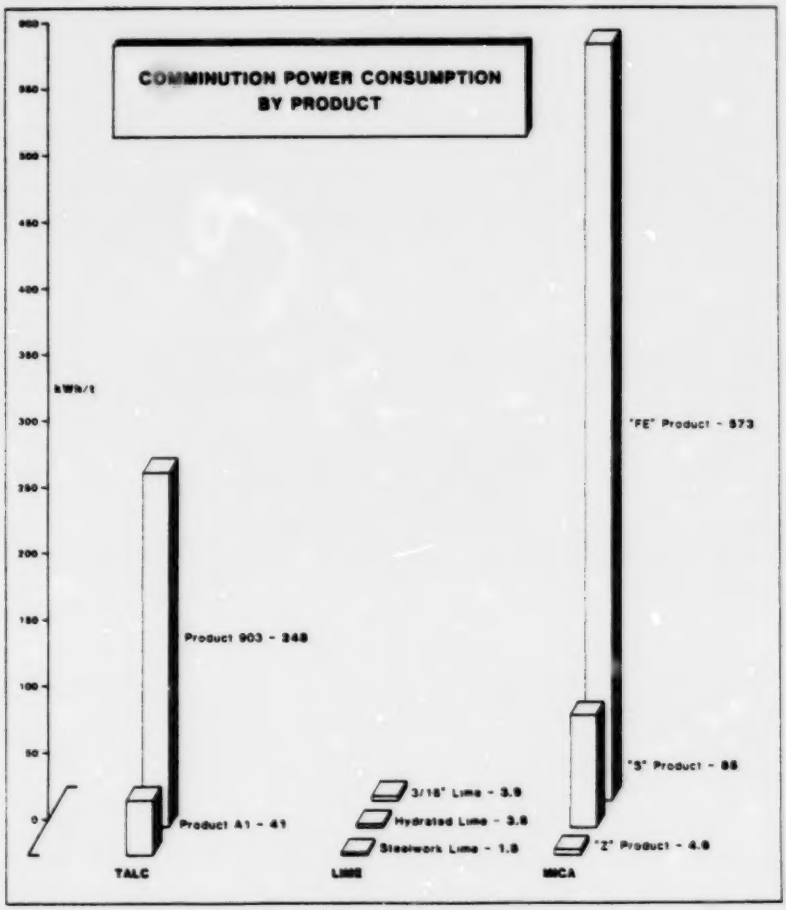
Silica

The fine products are energy intensive. Canadian sand produced from quartzite ores results in angular grains. It may be beneficial to investigate alternative grinding techniques to make round grained products to compete with imports.

Nepheline Syenite

Specific power consumption is high for finer products although these comprise a minor proportion of shipments. Energy conservation might be achieved by cutting down the number of size reduction stages in the process.

Group 3



Talc

Pulverized (95% -10 μm) product is energy intensive. Energy saving might be achieved through the use of pebble mills for grinding very fine product.

Lime

Power consumption in lime processing is low due to low grindability and coarse products. Most of consumption is for processing limestone for kiln feed. Lime itself involves minimal crushing and screening. Potential for energy conservation is low.

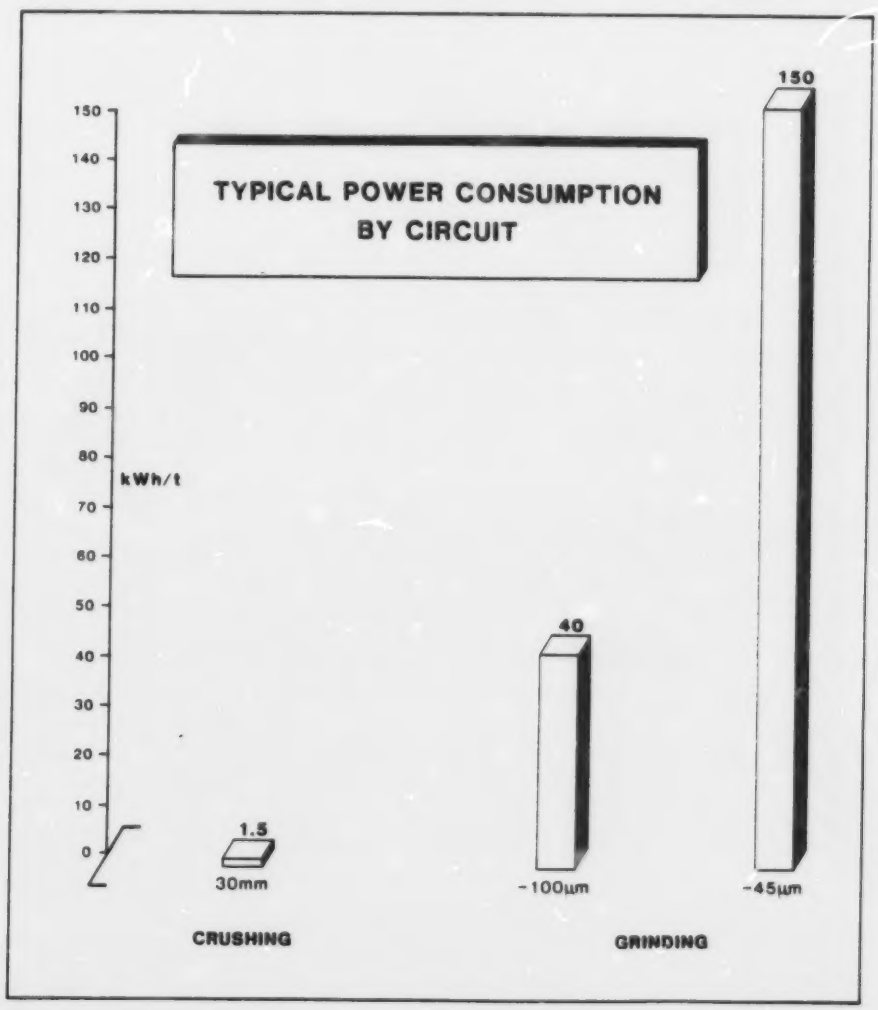
Mica

Industry power demand is low because annual production is only 11,000 tonnes.

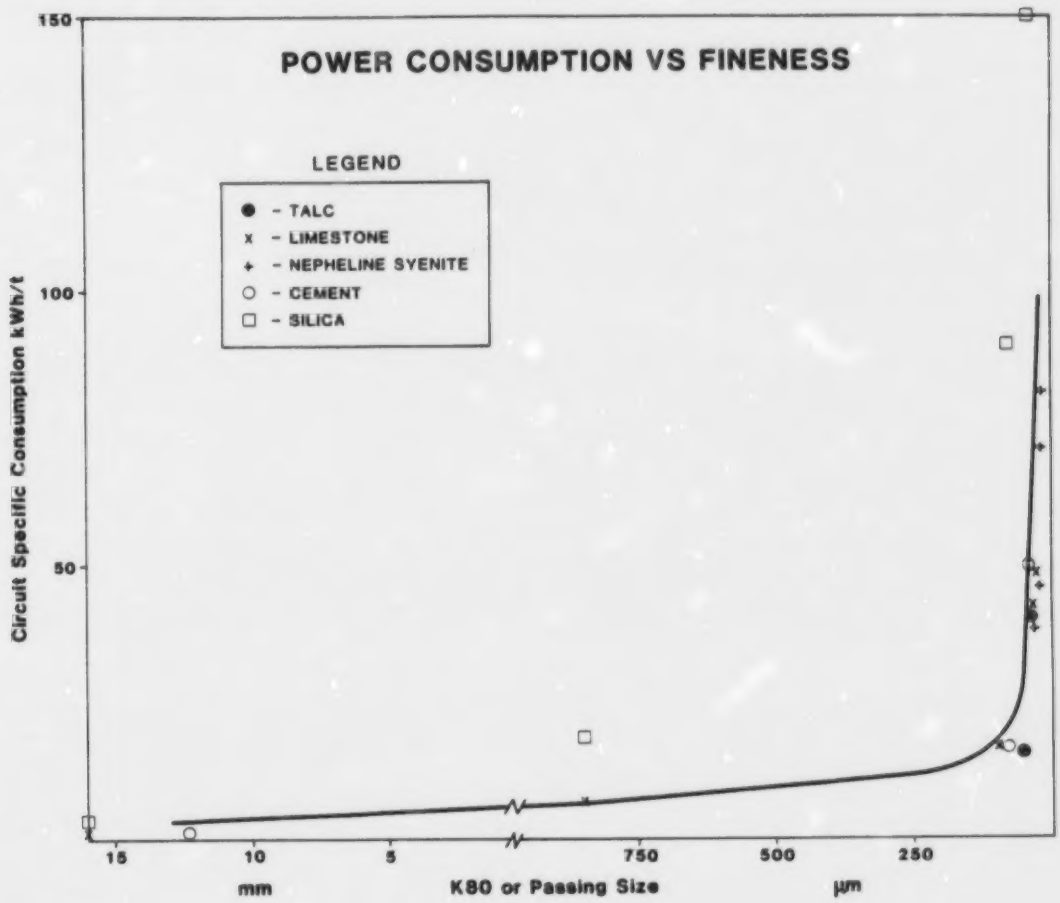
The high power consumption of the fine grinding circuit and the high abrasiveness of the mineral suggests that different milling techniques, equipment and material selection, and improved classification should be studied.

General Findings

Crushing uses considerably less power than grinding.



The power consumption in grinding increases sharply with the fineness of the product.



PHASE II ESTABLISHMENT OF PARTICLE SIZE MONITORING METHODOLOGY

RESULTS

A review of the available on-line particle size monitoring instruments indicated that further testing is needed before any can be regarded as satisfactory for use in industrial mineral processing.

The most developed systems are those based on light scattering. Of these, the Microtrac marketed by Leeds and Northrup is the most widely commercialized in North America.

The Microtrac can be used on wet or dry samples, although there are problems in ensuring dispersion of the particles in dry suspensions.

The instrument can scan the samples rapidly (25 seconds) and can cover a wide range of particle sizes (200 - 2 μm).

Comparison of the Microtrac with a Sedigraph, a laboratory instrument which measures particle sizes by sedimentation rates, indicated that for cement, the reproducibility of results of the two instruments is similar, but Microtrac readings for a given particle size tend to be higher than the Sedigraph.

The Microtrac results for the other industrial minerals were within the ±5% accuracy reported by the manufacturer.

A number of Microtrac units have been installed on-line in cement plants, but difficulties in presenting a suitably dispersed sample to the laser remain to be solved.

Automatic Blaine meters, which give a measure of specific surface area rather than a particle size distribution, are in operation in at least two cement plants for control of finish mills. The one installed in 1982 is apparently working satisfactorily. The other has just been commissioned.

We recommend that immediate action be taken to optimize comminution in the industrial mineral sector, so that the Canadian industry be in a strong position to compete with imports, to develop export markets and also be poised to take advantage of opportunities to supply fillers to the expanding plastics industry.

PHASE I

Specific Recommendations

Asbestos

Develop wet milling technology in order to reduce the power consumed in dust collection in dry milling.

Cement

Improve the classification of cement to reduce the amount of coarse and superfine material in the finished product. This represents an opportunity for Canadian manufacturers to develop new equipment or find ways of retrofitting existing classifiers.

Test the efficiency of other dry milling systems, for example, tower mills, for grinding clinker.

Mica

Test alternative milling systems for delaminating and grinding mica with a view to reduction of the power consumed in the manufacture of fine mica products with suitable aspect ratios.

Nepheline Syenite

Test the efficiency of autogenous milling to reduce the number of comminution stages.

Silica

Explore ways, for example use of attrition mills, to produce a ground silica with rounded grains suitable for foundry use to replace imports.

Talc

Investigate the use of pebble mills as a more efficient means of grinding superfine products.

General Recommendations

Investigate the action of grinding aids in preventing reagglomeration of particles in mill circuits. The investigation should involve research into the bonding forces between particles as well as pilot plant testing of commercial grinding aids.

Since crushing requires less power than milling, seek ways to optimize size reduction of mill feed in the crushing circuit.

Continue development of comminution circuit modeling to support development of mill control strategies.

Ensure transfer of information and technology to the industrial mineral industry by seminars and other means.

PHASE II

Investigate ways of dispersing and presenting dry samples to the Microtrac or other laser particle size analysers.

Test the performance of laser equipment under pilot plant conditions.

Test the performance of automatic Blaine meters.

Evaluate alternative ways of monitoring particle size, for example, using brightness.

Develop mill circuit control strategies using on-line particle size monitors.

PILOT PLANT PROPOSAL

It is proposed that, instead of constructing a new pilot plant, existing facilities be used to conduct a testing program which integrates the recommendations of this study with those of the survey made in 1982 by the Department of Energy, Mines and Resources into the problems and opportunities of the Canadian industrial minerals industry.

The Canadian Industry Program for Energy Conservation (CIPEC) reported a 15% reduction in energy consumption per tonne of output in 1982, compared to the base year 1974. Much of this saving could be attributed to improved housekeeping. Achieving further conservation would require process modification and fuel switching; both require R&D. The areas for work were grouped as follows:

general R&D - applicable to industrial mineral processing in general,

cement R&D - processing of Portland and other hydraulic cements and gypsum plaster,

clay products R&D - applicable to manufacture of brick, tile, pipe, etc.

The department of Energy, Mines and Resources (EMR) CANMET, wishing to assist the industrial minerals processing sector in improving the energy efficiency of its operations, commissioned this study.

The overall objective as stated by EMR was,

> to develop the necessary technology to optimize the comminution of industrial minerals in terms of direct and indirect energy consumption.

EMR defined direct and indirect energy consumption in the following way.

> Direct energy consumption measures the work done during the crushing and grinding operations and is expressed in kWh/tonne.

The indirect energy consumption is less frequently recognized and harder to quantify. Its effects are felt during secondary processing or utilization of comminuted materials. The correct size distribution of cement for example could command savings of up to 10% of the amount of cement necessary to make concrete. Optimization of comminution both in terms of kWh/tonne and in terms of processing energy consumption would make a major contribution to energy conservation in the industrial minerals processing sector.

Ten industrial minerals were chosen for study and, to achieve the objective, the work was divided by EMR into three phases.

Phase I

Plant studies to develop a data base. For each mineral, studies were made of power consumption during comminution at a plant whose operations are typical of the industry. The results are from a brief investigation of the company's operations and therefore, are descriptive rather than analytical.

Phase II

Establishment of monitoring methodology. An evaluation was made of commercially available particle size measuring equipment with a view to establishing the feasibility of mill circuit control by on-line particle size measurements.

Also under this phase, a proposal for a pilot plant test program was developed.

Phase III

Development of pilot plant system. Pilot plant development was not part of the scope of work.

Report Structure

The results of the study are presented at several different levels of detail.

- A summary report which contains the results of phase I and II and also the pilot plant proposal. The objective of this report is to give a general understanding of each of the industries which were studied, and a clear picture of the results without excessive detail.

  A typical print-out of the computerized data base is also included.

- Supporting volumes which contain for each industry, elaborate accounts of the in-plant testing programs, more detailed results, and some background information on the structure of the industry.

  Included also, is an expanded report on Phase II.

- Working papers which are available for consultation. These papers contain complete results of laboratory tests, recording charts and calculations.

In preparing these reports, care has been taken not to include information which could affect the competitive position of the cooperating companies. For this reason, some details which might be of interest to the reader have been specifically withheld.

The report does not give descriptions of the various types of crushing and grinding equipment because this has been done in numerous texts and reviews (for example, the report by SNC, Study on Energy Conservation in the Industrial Minerals Processing Sector Comminution Crushing and Grinding, Contract No. 18SQ 23440-1-9094).

The 1983 report on the Canadian Industry Program for Energy Conservation (CIPEC) gave a breakdown of energy use by the various industrial sectors. The emphasis of the report was on conservation achieved in 1982 when, despite the constraining effects of the recession, the member companies of CIPEC improved their energy efficiency by an average of 15.4%. The complete figures for 1983 are not yet available, but an overall improvement of 22% over the base year has been reported.

1982 Energy Use and Energy "Savings"* (Joules x 10^{15})

	1982 Energy Use	1982 Energy "Savings"
Chemicals	306.43	88.67
Electrical & Electronics	8.72	3.22
Farm & Industrial Equipment	n/a	n/a
Ferrous Metals	246.40	7.46
Food & Beverage	40.29	9.25
General Manufacturing	7.88	.28
Industrial Minerals	84.23	11.37
Machinery	1.34	.11
Mining & Metallurgy	101.50	7.41
Non-Prescription Medicine	.57	.38
Petroleum Refining	286.03	64.81
Plastics	1.35	.25
Pulp & Paper	299.70	61.40
Textiles	11.72	2.86
Transportation (Mfg.)	33.60	1.29
Wood Products (Western)	5.91	2.31
Total	1,435.67	261.07

* Additional energy that would have been used in 1982 without the efficiency improvements made since the base year.

Source: CIPEC

Industrial minerals is one of the top six energy using sectors, whose combined consumption is 92% of the industry total.

Sector	% of Total Industrial Energy Use
1) chemicals	21.3
2) pulp and paper	20.9
3) petroleum refining	19.9
4) ferrous metals	17.2
5) mining and metallurgy	7.1
6) industrial minerals	5.8
other sectors	7.8

Energy consumption by source for each of the sectors, is shown in the table below.

1982 Task Force Energy Consumption

	Purchased Fuel Consumption (% of Total)					
	Natural Gas	Liquid Petroleum	Electric Power[1]	Coal & Coke	Propane LPG	Other Fuels[2]
Chemicals	62.4	16.6	17.0	nil	nil	4.0
Electrical & Electronics	56.9	7.3	33.8	nil	nil	0.8
Farm & Industrial Equipment	n/a	n/a	n/a	n/a	n/a	n/a
Ferrous Metals	19.3	8.6	6.9	65.2	nil	nil
Food & Beverage	65.8	19.3	14.5	nil	0.4	nil
General Mfg.	52.2	19.6	27.7	nil	0.5	nil
Industrial Minerals	42.4	15.3	13.6	28.8	nil	nil
Machinery	49.8	10.6	37.2	1.5	0.8	nil
Mining & Metallurgy	17.1	31.5	43.8	5.2	2.3	nil
Non-Prescription Medicine	74.8	0.3	24.9	nil	nil	
Petroleum Refining	13.1	19.4	4.2	14.9	1.9	46.4
Plastics	54.1	1.3	43.3	nil	1.3	nil
Pulp & Paper	25.7	37.9	31.9	3.3	0.2	0.9
Textiles	26.5	46.6	23.3	nil	3.6	nil
Transportation (Manufacturing)	53.0	10.1	27.0	9.5	0.4	nil
Wood Products (Western)	55.5	nil	44.5	nil	nil	nil
Total of All Task Forces	29.5%	22.1%	18.7%	18.0%	0.7%	11.0%

[1] The Chemicals and Petroleum Refining sectors report their electric power use at the higher "gross" energy content levels. For purpose of CIPEC industry-wide compilations, these have been converted to the "standard" 3.6×10^6 J/kWh used by the other task forces. Thus the data in CIPEC displays will not compare directly with those presented in the Chemicals and Petroleum Refining Task Force reports.

[2] Other Fuels include by-products and waste, purchased steam, refinery gas and miscellaneous fuels, but exclude wood wastes, though these continue to be a major energy source for the forest products and pulp and paper sectors.

Source: CIPEC

Within the industrial minerals group, the cement and glass subsectors account for 74% of the sector's energy consumption.

Industrial Minerals Industry
Reported Data 1982

Subsector	1982 Total Energy Joules x 10^{15}	% of Total
Abrasives	1.865	2.2
Asbestos	7.290	8.7
Cement	42.569	51.8
Clay Brick	3.544	4.2
Concrete Products	0.350	0.5
Glass	19.332	22.9
Lime	7.382	8.8
Miscellaneous	1.051	1.3
Refractories	0.846	0.9
Totals	84.229	100.0

Source: CIPEC

Fuel represents 86% of the sector's energy demand.

Industrial Minerals Industry
Energy Use 1982

Subsector	Fuel		Electricity		Total
	Joules x 10^{15}	%	Joules x 10^{15}	%	J x 10^{15}
Cement	38.8	91.1	3.8	8.9	42.6
Glass	14.7	76.2	4.6	23.8	19.3
Other	19.2	86.1	3.1	13.9	22.3
Total	72.7	86.3	11.5	13.6	84.2

Source: CIPEC

Power used in Comminution

It is not possible from published data to isolate power used in comminution from total power demand in the industrial minerals sector.

However, in the case of cement, more than 50% of power demand is attributable to comminution, based on the following breakdown:

Typical Cement Power Use

	kWh/t	%
Comminution	76	54
Other	64	46
Total	140	100

In a number of the other industrial minerals, particularly those with finely ground filler products, comminution will account for a considerably greater proportion of power consumption.

Power Costs

Industrial minerals are not defined as a sector in the Standard Industrial Classification (SIC) codes and therefore are not reported on as a unit by Statistics Canada.

The minerals are classed by the SIC as follows:

Code		Industry
06		Mining
	062	Non-Metal Mines
08		Quarry & Sand Pit Industries
	081	Stone Quarries
	082	Sand & Gravel Pits
35		Non-Metallic Mineral Products
	352	Hydraulic Cement Industry
	356	Glass and Glass Products Industry
	358	Lime Industry
	359	Other Non-Metallic Mineral Products Industries

The published information on these groups allows partial comparison of cost of electricity compared to fuel. The data is summarized in the table below.

Consumption of Purchased Fuel and Electricity 1980 ($000)

	Fuel	Electricity	% Electricity
Mining Industry			
Metal Mines	$ 220,052	$ 174,837	45
Non-Metal Mines			
Asbestos Mines	39,340	13,537	26
Gypsum Mines	1,605	1,134	41
Potash Mines	35,260	19,415	35
Other	18,451	5,715	25
Total	96,238	40,366	29
Quarries & Sand Pits			
Stone Quarries	8,437	5,957	43
Sand Pits & Quarries	7,998	2,012	20
Total	16,434	7,970	33
Total Mines, Quarries & Oil Wells	365,305	341,100	48
Manufacturing Industry			
Non-Metallic Mineral Products			
Cement Manufacture	103,364	32,789	24
Glass & Glass Products Manufacture	37,155	13,021	26
Lime Manufacture	35,220	3,231	8
Misc. Non-Metallic Mineral Products	33,963	17,593	35
Total Non-Metallic	271,483	102,765	28
Total Manufacturing	$2,689,664	$1,759,195	40

Source: StatsCan

In the non-metal mines and non-metallic mineral products groups, power represents an average of 29 and 28%, respectively, of total energy cost.

The industrial minerals sector is not as large an energy consumer as ferrous metals or mining and metallurgy. The comparative figures for 1982 are:

	Joules x 10^{15}
- ferrous metals	246.4
- mining and metallurgy	101.5
- industrial minerals	84.2

However, the energy used in comminution per tonne processed in the industrial minerals sector is considerably greater than that in metallic mineral processing. The table below summarizes power consumption in crushing and grinding of a number of metallic ores.

Energy Consumed in Comminution in Metallic Mineral Processing

Ranges kWh/t

Metallic Ore	Crushing	Grinding
Iron	0.9 - 5.4	2.7 - 27.3
Copper	0.1 - 7.1	6.7 - 25.1
Nickel-Copper	2.4 - 13.5	9.6 - 15.8
Copper-Lead-Zinc	1.0 - 11.	10.7 - 19.3
Lead-Zinc	1.4 - 5.5	12.7 - 15.7
Molybdenum	1.0 - 6.8	8.4 - 10.3
Gold and Silver	1.6 - 9.0	13.5 - 111.1
Uranium	5.1 - 5.5	10.5 - 13.7

Source: E.G. Joe, CIM Bulletin, June 1979.

Energy used in crushing is similar for the metallic and industrial minerals, but with the exception of gold and silver ores, grinding energy consumption ranges between 2.7 and 27.3 kWh/t for the metallic minerals. In the industrial mineral processing sector, grinding energy consumption ranges from 16.9 - 488.0 kWh/t, depending on the grindability and fineness of the product.

Since energy consumed in comminution is so significant in the industrial minerals sector, R & D action aimed at improving crushing and particularly grinding will strengthen the ability of the industry to replace imports and compete in export markets.

Plant Studies to Develop Data Base

Studies shall be focused on the establishment of crushing/grinding characteristics and requirements for specific industrial minerals from the standpoint of both physical characteristics and energy consumption and with regard to required product specifications. The minerals of current concern include -- cement, lime, gypsum, asbestos, nepheline syenite, silica, limestone, talc, mica and potash. Plant studies of typical operations for each of the noted industrial minerals shall be made. The studies shall involve compilation of data which include the following parameters:

(a) operating conditions as defined by plant management;

(b) material balance;

(c) particle characteristics and particle size distribution of various stages of crushing and grinding, of the final product(s), of the recirculating load and of any waste from by-product streams;

(d) direct energy consumption at each comminution stage;

(e) product properties as defined by specifications and user requirements;

(f) variability of all measured parameters.

The objective shall be to relate direct and indirect energy consumption to objective measurements during the various stages of crushing and grinding. These data shall be used to build mathematical models of circuit performance with respect to energy and desirable product characteristics as a basis for optimization. Data and analysis from this phase of the work shall be interfaced with the CANMET's Simulated Processing of Ore and Coal Project (SPOC). REF. MRP/MSL 80-179 (OP&J).

Each industry was studied in basically the same fashion which is outlined below:

- a background review was made to gain an understanding of the industry, its products, process and the role of comminution,

- a brief visit was made to the cooperating plant to develop with the assistance of plant personnel process flow sheets, to define the comminution circuits measurement programs, to establish product specifications and quality control methods,

- a subsequent 2-5 day visit was made to take the requisite electrical measurements, establish material flowrates and to take samples for particle size analysis and grindability testing at CCL's central laboratory,

- the data was reviewed, calculations of specific energy consumption were made for each comminution stage and comminution energy input to each product,

- an industry report was prepared and the results entered in a computerized data base.

The above methodology was suitable for measuring direct energy consumption. Because of the shortage of time with each industry, the only case of indirect energy consumption that came to our attention was in cement, where inefficient classification results in excessive coarse and superfine particles in the product.

The results obtained in this way are a "snapshot" of a plant's operation. It is assumed that the snapshot is representative of normal operations and that the plant is typical of the industry as a whole.

PARTICIPATING COMPANIES

Mineral	Company	Plant Location
Asbestos	Lac d'Amiante du Québec, Ltée	Black Lake, Quebec
Cement	Canada Cement Lafarge Ltd.	St. Constant, Quebec
Gypsum	Domtar Incorporated	Caledonia, Ontario
Lime	Domtar Incorporated *	Joliette, Quebec
Limestone	Domtar Incorporated *	Joliette, Quebec
	Steep Rock Resources Inc.	Perth, Ontario
Mica	Marietta Resources International, Ltd.	Boucherville, Quebec
Nepheline Syenite	International Minerals & Chemical Corporation	Blue Mountain, Ontario
Potash	P.C.S. Mining Ltd. Cory Division	Saskatoon, Saskatchewan
Silica	Operating plant unavailable.	
Talc	Bakertalc Incorporated	Highwater, Quebec

* Joliette plant now owned by Jolichaux Inc.

ASBESTOS

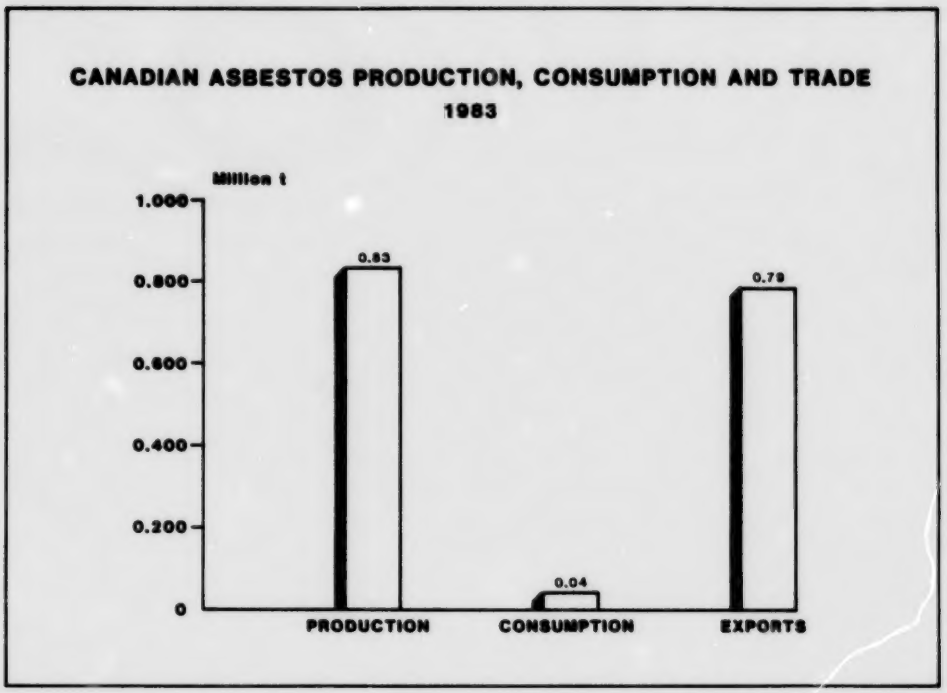
Participating Company

LAC d'AMIANTE DU QUÉBEC, LTÉE

Plant Location

Black Lake, Quebec

Asbestos: High specific power consumption - large tonnages processed, major export commodity



Source: Canadian Mining Journal, February 1984.

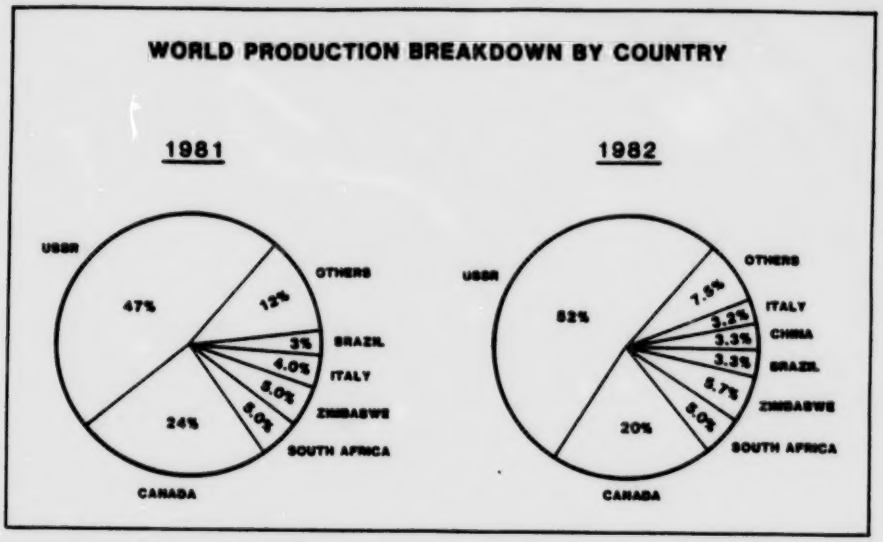
Comminution power requirement : 223 kWh/t of fiber.

Estimated comminution power requirement by the asbestos industry in 1983 : 184,600,000 kWh.

Background

Canada, with 20%, is the world's second largest producer of asbestos after the USSR, which accounts for 52% of annual production. Zimbabwe is third with 5%.

The Canadian asbestos industry is concentrated in the Eastern Townships of Quebec, smaller amounts are produced in British Columbia and Newfoundland.

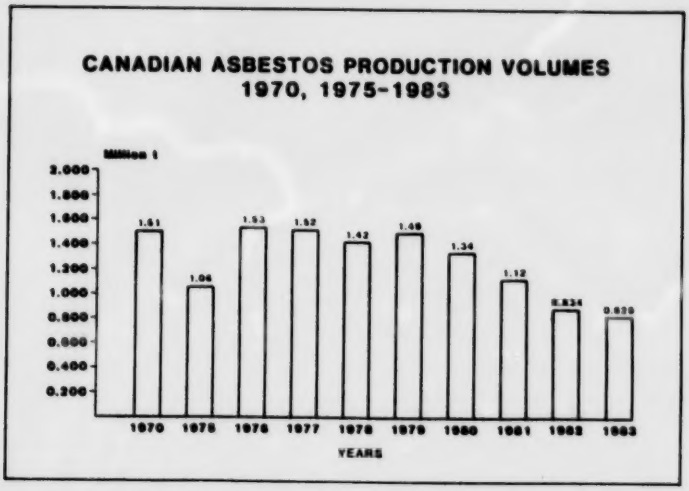


Source: Canadian Mining Journal, February 1983 & 1984.

During 1983, the production was 829,000 tonnes, with a value of $402.3 million.

Exports account for about 95 percent of Canadian production. This represents 50 percent of world export trade in asbestos.

Recessionary conditions in the construction industry, plus uncertainties regarding future environmental regulations and adverse publicity regarding exposure to dust in industry, have reduced shipments of asbestos fibre in the last few years.



Source: Canadian Mining Journal, February 1983 & 1984.

Products and Uses

Chrysotile asbestos is the result of an alteration and metamorphosis of basic igneous rocks rich in magnesium silicate. Impurities are iron, chrome and nickel. A typical chemical composition and relevant physical properties are summarized in the tables below.

APPROXIMATE COMPOSITIONS CHRYSOTILE ASBESTOS	
Component	% By Weight
SiO_2	37-44
MgO	39-44
FeO	0-6
Fe_2O_3	0.1-5
Al_2O_3	0.2-1.5
H_2O	12-15

PHYSICAL PROPERTIES		
Specific Heat	:	1.113 J/kg.K
Specific Gravity	:	2.55 gm/cc
pH	:	9.6 - 9.75
Tensile Strength	:	552 - 689 MPa
Fusion Point	:	1520°C
Electrical Charge	:	Positive

The asbestos industry has classified and priced its products by groups from the longest and most expensive fibre to the shortest and cheapest fibre.

The major uses for chrysotile asbestos fibre are:

POSSIBLE USES OF CHRYSOTILE ASBESTOS FIBRE		
Fibre Class	**Groups**	**Uses**
LONG	1 and 2 Crudes	Processed industrially into long spinning fibres used in textiles and the electrical industry.
	3 Milled	Textiles, asbestos papers, packings, brake linings, clutch facings, pipe coverings, and insulating blocks.
MEDIUM	4 Milled	Reinforcing in asbestos-cement products: pipe, shingles, jackets pipe coverings, asbestos-cement packing, gaskets, millboards, roof coatings and plastics.
	5 Milled	Asbestos-cement sheets, corrugated or flat boards, pipes, electrical panels, asbestos papers, millboards, pipe coverings, brake linings, asbestos-cements, roof coatings, putties and plastics.
	6 Milled	Asbestos-cement shingles, corrugated or flat sheets, boards, brake linings, asbestos papers, millboards, asphalt roof coatings, putties and plastics.
SHORT	7, 8, 9 Milled	Certain papers, insulating cement, asphalt roof coatings, putties, paints, welding rods, floor tiles, plastics, acoustical plaster, fibrated greases, oil well muds.

Each group is subdivided into subgroups according to the fibre's openness; that is, how finely the fibres have been distributed. "Openness" has a considerable effect on the properties of the manufactured production which the fibre is to be used.

Since there are numerous uses for asbestos fibre, processing plants must be able to ship a range of products. Quebec producers, for example, supply some 150 different classifications.

Testing programs monitor and control the flow of fibre in production and assure that finished fibre grades meet both the quality and uniformity specifications. Most tests measure properties related to fibre length distribution, degree of openness, strength unit, and filtration rate.

QAMA Standard Tests
FIBRE LENGTH 1. Quebec standard screen 2. Ro-Tap screen 3. Bauer-McNett screen 4. Suter Webb comb 5. Wash test for 200 mesh fines
FIBRE OPENNESS 1. Wet volume or buoyancy 2. Loose density or dry bulk 3. Surface area by air permeability 4. Crudy or grit content 5. Viscosity 6. Kerosene retention 7. Penetration index 8. Oil absorption
MISCELLANEOUS 1. Tensile strength 2. Asbestos-cement strength 3. Color 4. Quantitative chemical analysis 5. Moisture content 6. Magnetic rating 7. Freeness or filtration

The Production Process

Production of asbestos fibre requires mining of enormous amounts of ore, as the asbestos-dry rock ratio is about 5%. Normally, two-thirds of a day's mining production is rejected, leaving the remaining one-third to enter the processing plant.

There are four process operations, crushing, drying, milling, and grading; the first three involving comminution, as the flow sheet on page 19 shows.

The selected ore as received from the mine goes through primary and secondary crushing and then is dried in preparation for milling. The moisture content is reduced to between 1.5 and 0.5 percent. The ore is beneficiated by eliminating 45 percent of the gangue material.

The beneficiated material is milled to release the fibres from the host rock which are then graded to achieve specific product characteristics.

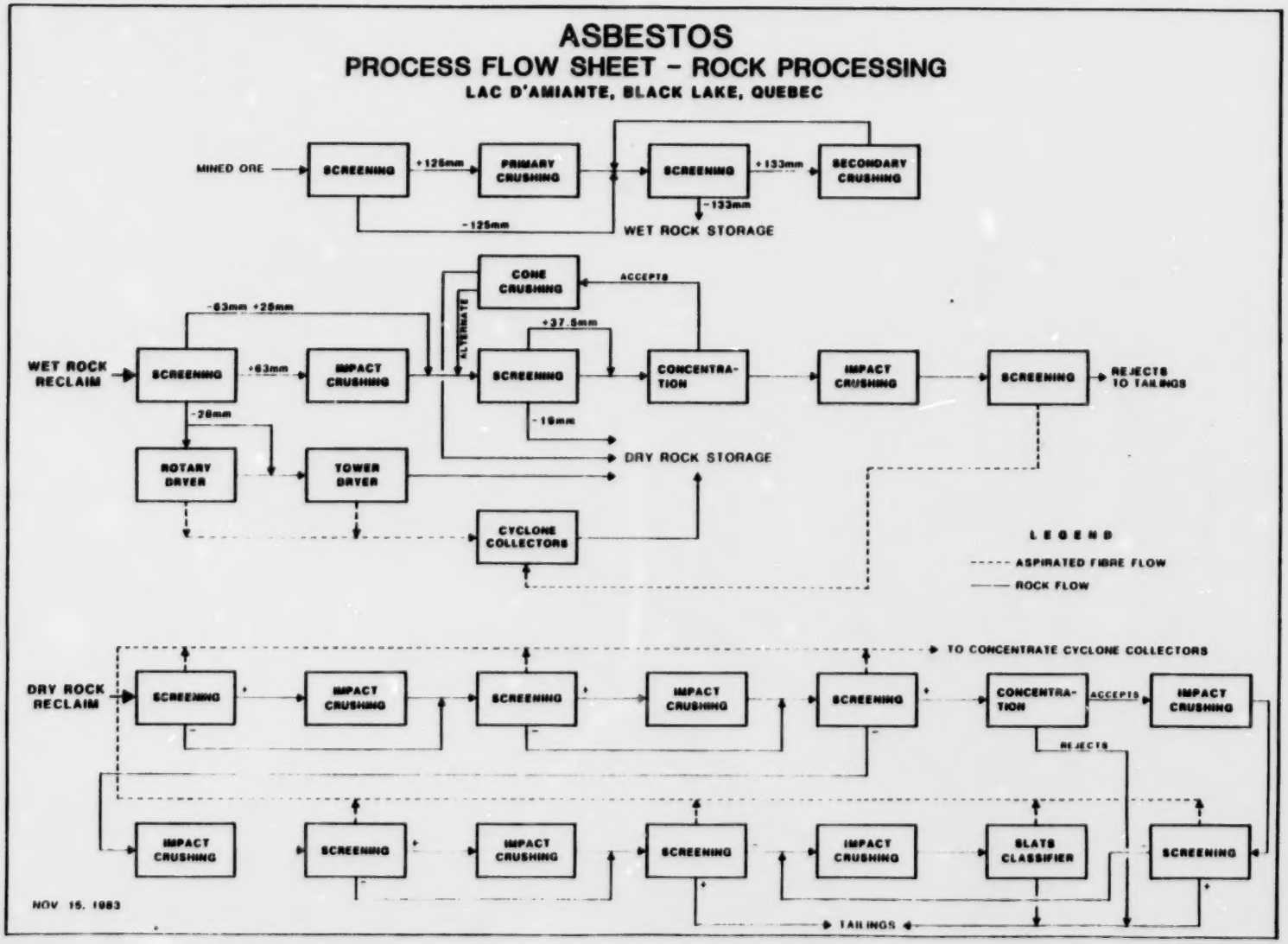
The Role of Comminution

There are three comminution steps in asbestos manufacture.

Crushing, where mined ore is reduced to a size suitable for the drying circuit.

Drying, is the ore preparation circuit. The objectives are to reduce the moisture content to acceptable levels of 1.5 to 0.5 percent and the removal of iron and other undesirable material to tailings, which approximates 45 percent of the feed. Impactors and a cone crusher are the equipment used in the circuit.

ASBESTOS
PROCESS FLOW SHEET – ROCK PROCESSING
LAC D'AMIANTE, BLACK LAKE, QUEBEC



Milling, is the fibre production circuit. There are several levels of milling; each involving screening, aspiration, and impacting. The purpose is to allow the fibre to be drawn off to cyclone collectors and to eliminate the host rock.

Comminution at Lac d'Amiante

The Crushing Circuit

The flow diagram with power levels in kilowatts is shown on page 21.

The **flowrate** is 750 t/h to the apron feeder.

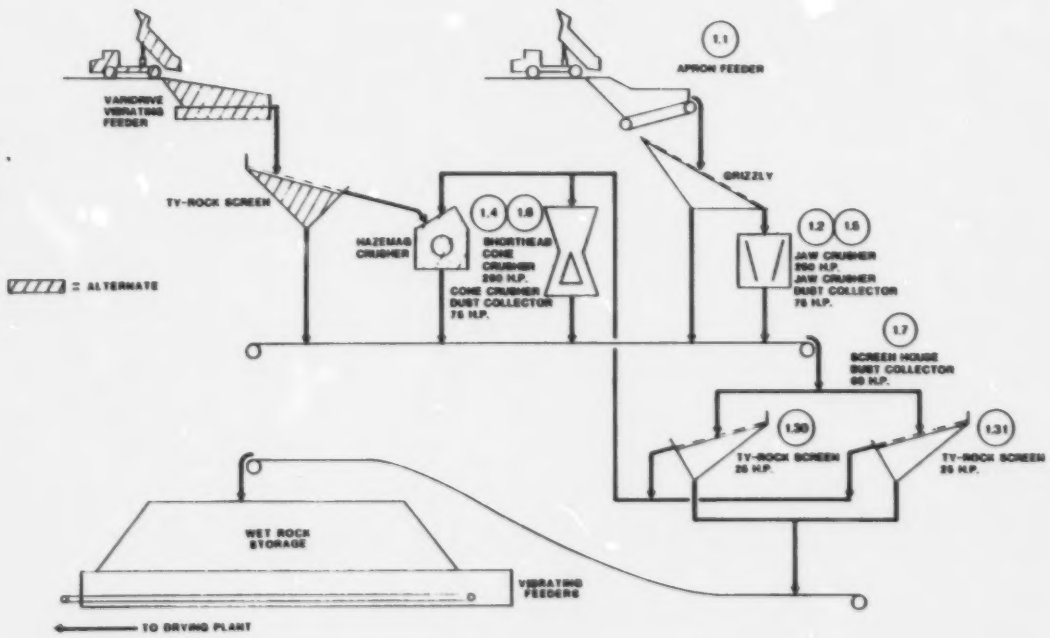
Grindability tests by the Hardgrove and Bond methods were tried but were unsuccessful because of the fibrous nature of the material.

Size distribution. No samples of the feed were taken because of the large dimensions of the rock. However, the distribution on the apron feeder ranged from 1m x 1m x 0.3m to fines. Between 30-40 percent passes directly through the 127 mm grizzly to the secondary screens together with the primary crusher discharge.

Secondary screening discharge, less than 133 mm, provides the drying circuit feed.

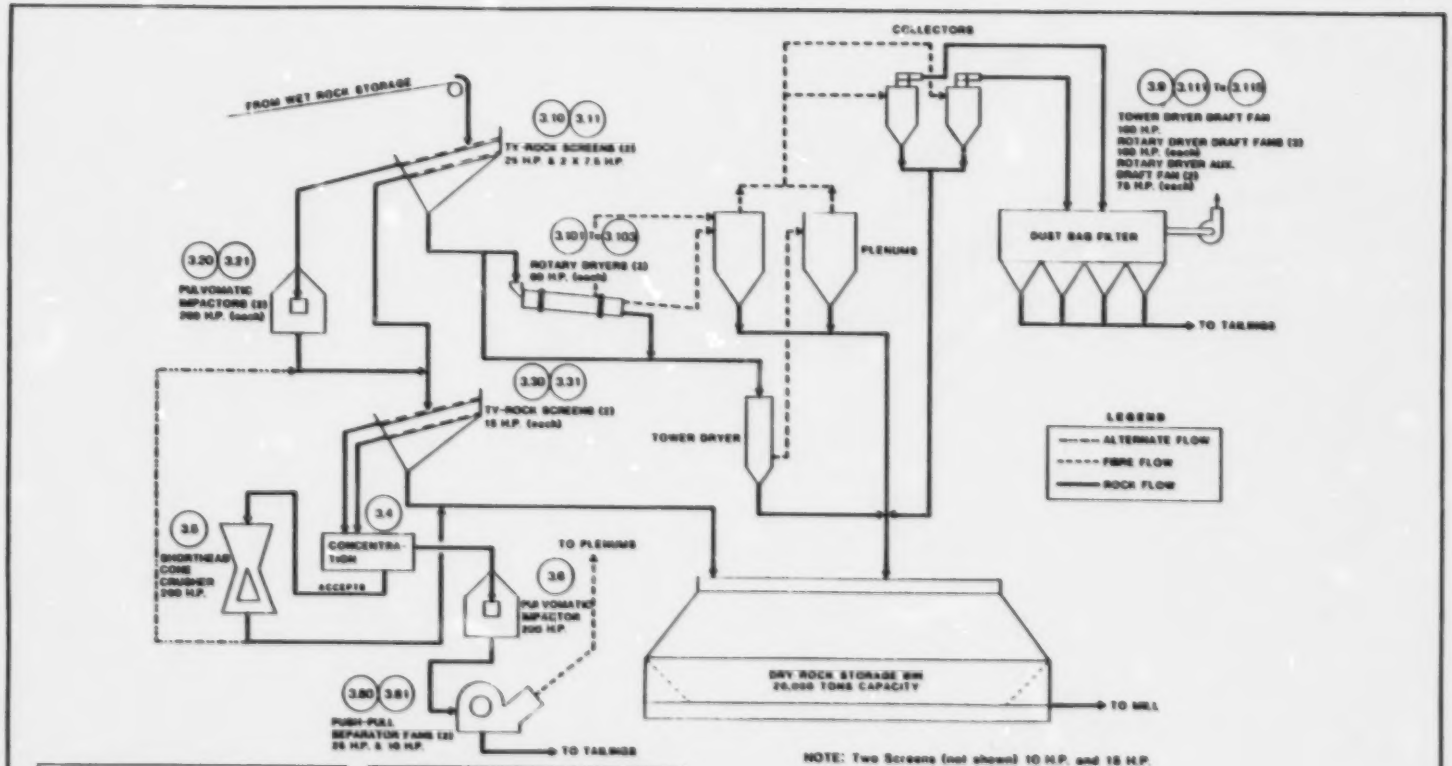
The Drying Circuit

The flow diagram and equipment power levels in kilowatts are shown on page 22.



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
1.1	Apron Feeder	11.1/7.5
1.2	Jaw Crusher	153
1.30	Ty-Rock Screen-F800	4.9
1.31	Ty-Rock Screen-F800	5.0
1.4	7' Shorthead Cone Crusher	136
1.5	Jaw Crusher Dust Collector	23
1.6	Cone Crusher Dust Collector	18
1.7	Screen House Dust Collector	43

CANADA CEMENT LAFARGE LTD. MONTREAL		
DRAWN GFJ DATE 18/11/83	CRUSHING CIRCUIT FLOW DIAGRAM	PLANT of LAC D'AMIANTE BLACK LAKE, QUEBEC
CHECKED DCB DATE 20/09/84		PROJECT No. 20010



NOTE: Two Screens (not shown) 10 H.P. and 15 H.P.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
3.10	Ty-Rock Screen - F600	8.6
3.11	Ty-Rock Screen - F600	2x2.6
3.20	Pulvomatic Impactor	89
3.21	Pulvomatic Impactor	90
3.30	Ty-Rock Screen - F600	4.3
3.31	Ty-Rock Screen - F600	4.4
3.4	Concentration	15.4
3.5	5-1/2' Shorthead Cone Crusher	68
3.6	Pulvomatic Impactor	103
3.70	Screen	3.4
3.71	Screen	12.8

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
3.80	Push-Pull Separator Fan	15.6
3.81	Push-Pull Separator Fan	5.2
3.9	Tower Dryer Draft Fan	72
3.101	Rotary Dryer Drive #2	-
3.102	Rotary Dryer Drive #3	47
3.103	Rotary Dryer Drive #4	55
3.111	Rotary Dryer Draft Fan #2	-
3.112	Rotary Dryer Draft Fan #3	49
3.113	Rotary Dryer Draft Fan #4	53
3.114	Auxiliary Draft Fan	44
3.115	Auxiliary Draft Fan	39

CANADA CEMENT LAFARGE LTD.
MONTREAL

Drawn GF.J Date 16/11/83
Checked DCB Date 20/09/84

DRYING CIRCUIT FLOW DIAGRAM

Plant of LAC D'AMANTE BLACK LAKE, QUEBEC

PROJECT No. 20010

The **flowrate** depends on the moisture content and is seasonal, being slowest in the winter. The reclaim rate from wet rock storage was 655 t/h and the beneficiated feed to dry rock storage was 344 t/h.

The objective is to condition and dry the ore. The smaller sizes, less than 28 mm, contain the moisture and require drying. The larger sizes are crushed, screened, concentrated by removing the magnetic material, crushed again and sent to dry rock storage.

The rejects are crushed again, then aspirated to recover some additional fibre, with the remainder going to tailings.

Size distribution of the feed and product from the Ty-Rock screen impactor, cone crusher and concentration impactor are summarized in the next table.

Drying Circuit Size Distribution (% Passing)

	TY-ROCK SCREEN IMPACTOR		CONE CRUSHER		CONCENTRATION IMPACTOR	
mm	Feed	Disch.	Feed	Disch.	Feed	Disch.
133	100				100	100
75		100	100		95.5	99.2
50	47.9	85.0	88.0	100	76.8	88.0
38.1			79.0	94.4		
25.0	9.2	48.9	49.7	68.1	31.3	56.4
19.0	5.2	36.7	26.0	36.7	12.2	40.4
12.5	2.9	24.7	5.7	12.7	1.9	22.3
9.5			5.3	10.2		
6.3		14.0			0.7	10.4
4.75			2.6	6.8		
2.36			2.2	4.8		
1.60						3.9

Milling

The flow diagram with the equipment power demands is shown on page 25.

During the study, the **feedrate** to the circuit was measured at 323 t/h.

Size distributions of the material flow through the system are as shown.

LAC D'AMIANTE DU QUÉBEC, LTÉE
Mill Rock Circuit
Size Distributions (% Passing)

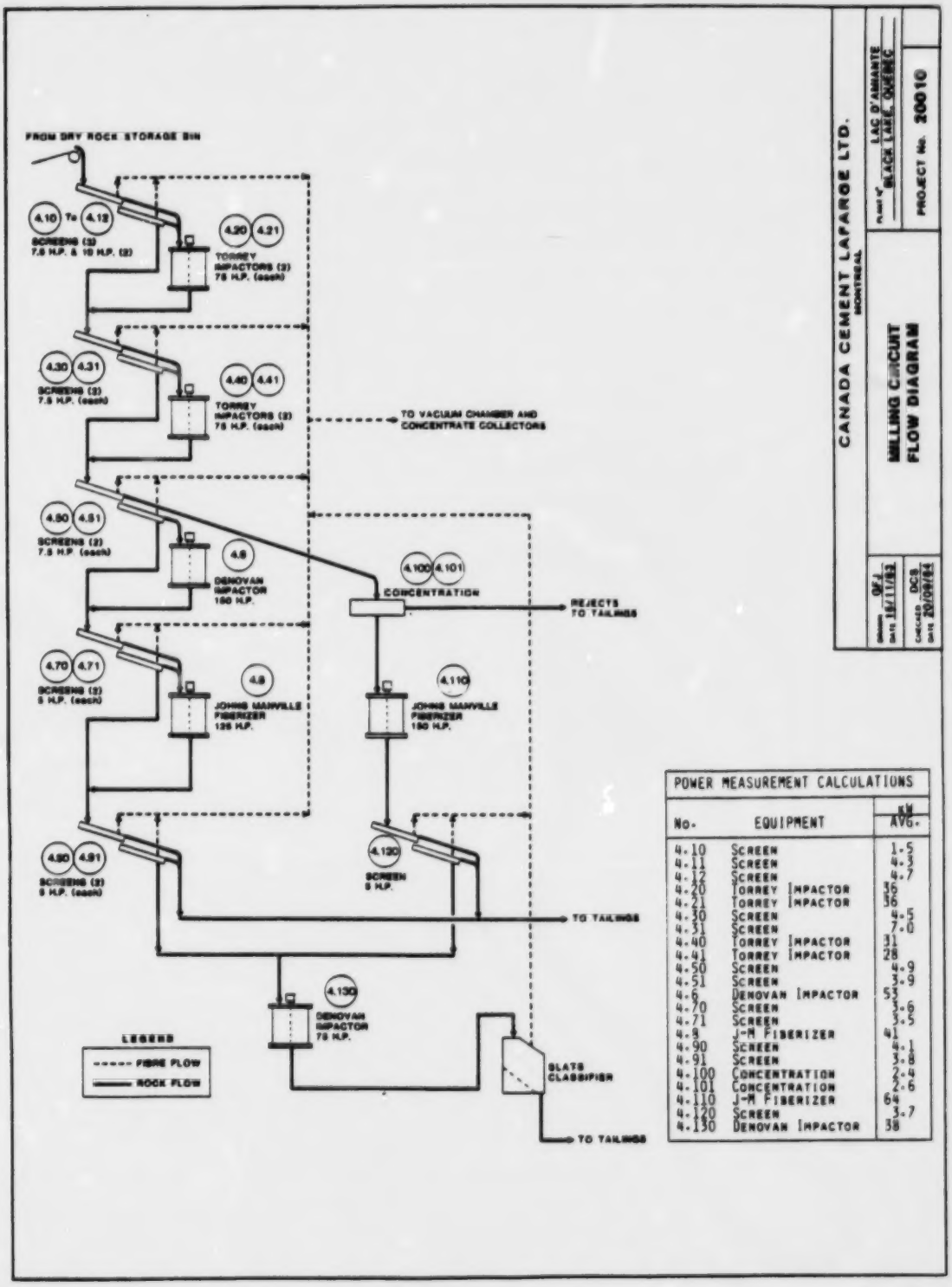
mm	TORREY (4.2)		TORREY (4.4)		DENOVAN (4.6)		J.M. FIBERIZER (4.8)	
	FEED	DISCH.	FEED	DISCH.	FEED	DISCH.	FEED	DISCH.
50	100	100	100					
38.1	99.0	99.8	99.7	100				
25.0	95.0	99.3	98.4	99.8				
19.0	88.0	96.5	95.0	99.3				
16.0	80.5	94.8	90.9	98.4				
12.5	65.4	89.6	81.8	95.1	100			
9.5	44.7	79.9	65.7	87.4		100		
6.3	23.8	64.9	47.1	74.9	53.9	73.9	100	100
2.36	6.0	39.5	18.4	43.9	28.8	40.6	57.3	84.7
1.40	3.3	25.0	6.2	24.6	11.4	18.9	13.2	57.6
1.00	2.7	17.9	3.8	17.1			7.4	39.8
0.600	2.4	13.5	2.2	12.4	4.6	7.3	3.7	28.7
0.425	1.4	9.9	1.6	9.1			3.0	21.0

Grading & Aspiration

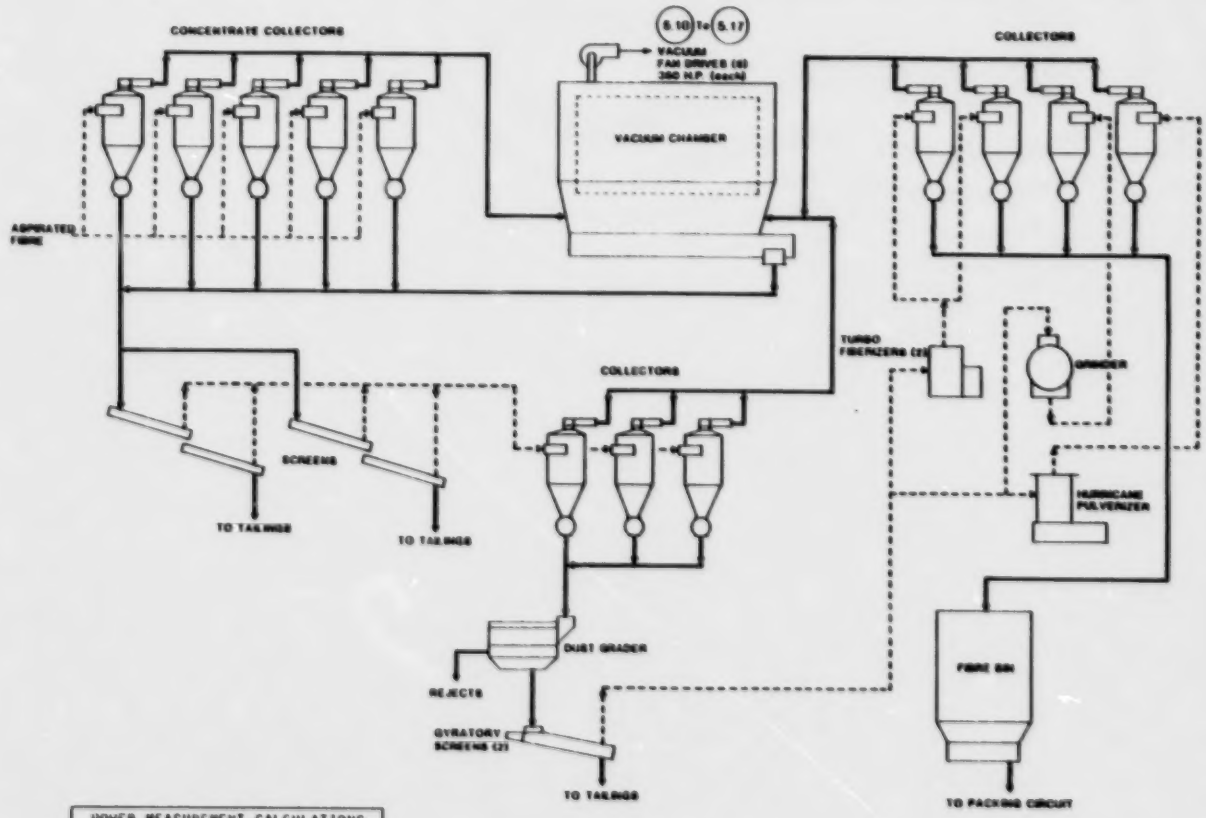
The circuit is shown diagrammatically on the flow diagram on page 26 with the equipment power levels.

The fibre production rate was determined to be 17.85 t/h.

The aspiration system is large and significant in asbestos production. The vacuum chamber processes 336,000 m^3 per minute through 21,000 polyester bags.



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
4.10	Screen	1.5
4.11	Screen	4.3
4.12	Screen	4.7
4.20	Torrey Impactor	36
4.21	Torrey Impactor	36
4.30	Screen	4.5
4.31	Screen	7.0
4.40	Torrey Impactor	31
4.41	Torrey Impactor	28
4.50	Screen	4.9
4.51	Screen	3.9
4.6	Denovan Impactor	53
4.70	Screen	3.6
4.71	Screen	3.5
4.8	J-M Fiberizer	41
4.90	Screen	4.1
4.91	Screen	3.8
4.100	Concentration	2.4
4.101	Concentration	2.6
4.110	J-M Fiberizer	64
4.120	Screen	3.7
4.130	Denovan Impactor	38



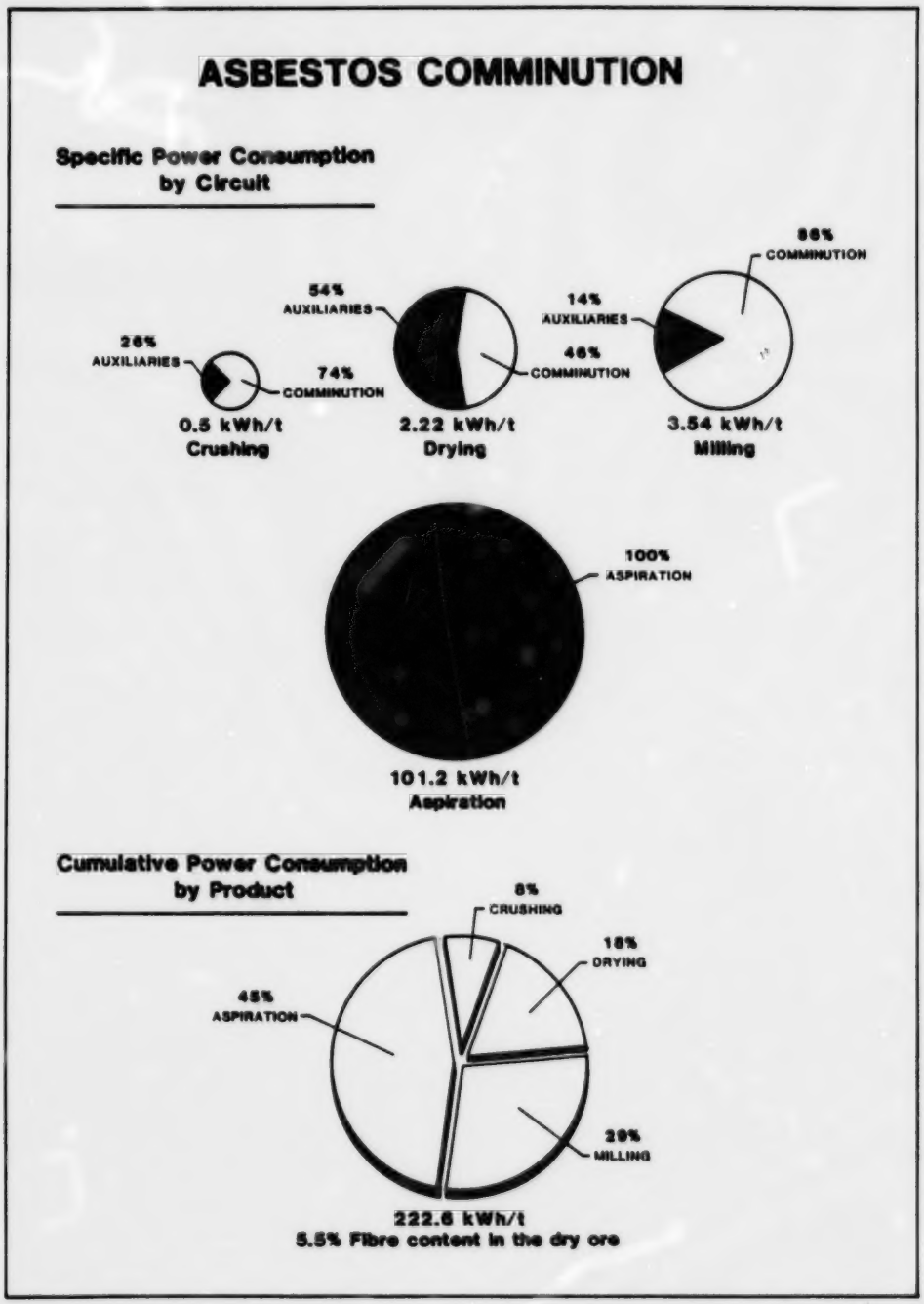
POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
5.10	Vacuum Fan Drive #1	217
5.11	Vacuum Fan Drive #2	223
5.12	Vacuum Fan Drive #3	239
5.13	Vacuum Fan Drive #4	226
5.14	Vacuum Fan Drive #5	219
5.15	Vacuum Fan Drive #6	226
5.16	Vacuum Fan Drive #7	209
5.17	Vacuum Fan Drive #8	247

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN GF J DATE 16/11/83	ASPIRATION AND GRADING CIRCUIT FLOW DIAGRAM	PLANT LAC D'AMIANTE BLACK LAKE, QUEBEC
CHECKED DCS DATE 20/09/84		PROJECT No. 20010

Results

The specific power consumption in the crushing, drying and milling circuits are summarized below.



Conclusions

From the study, it can be concluded that:

- the results are considered as a fair representation of the power consumption for comminution by the industry;
- the air handling system is a significant energy consumer;
- the fibre to dry rock ratio of 5.53 percent requires the mining of large quantities of ore to achieve required production rates;
- many comminution stages are required to continuously release the fibre from the host rock.

Recommendations

Due to the stringent dust control requirements and the present high energy consumption of the air handling system, the use of wet grinding should be investigated.

CEMENT

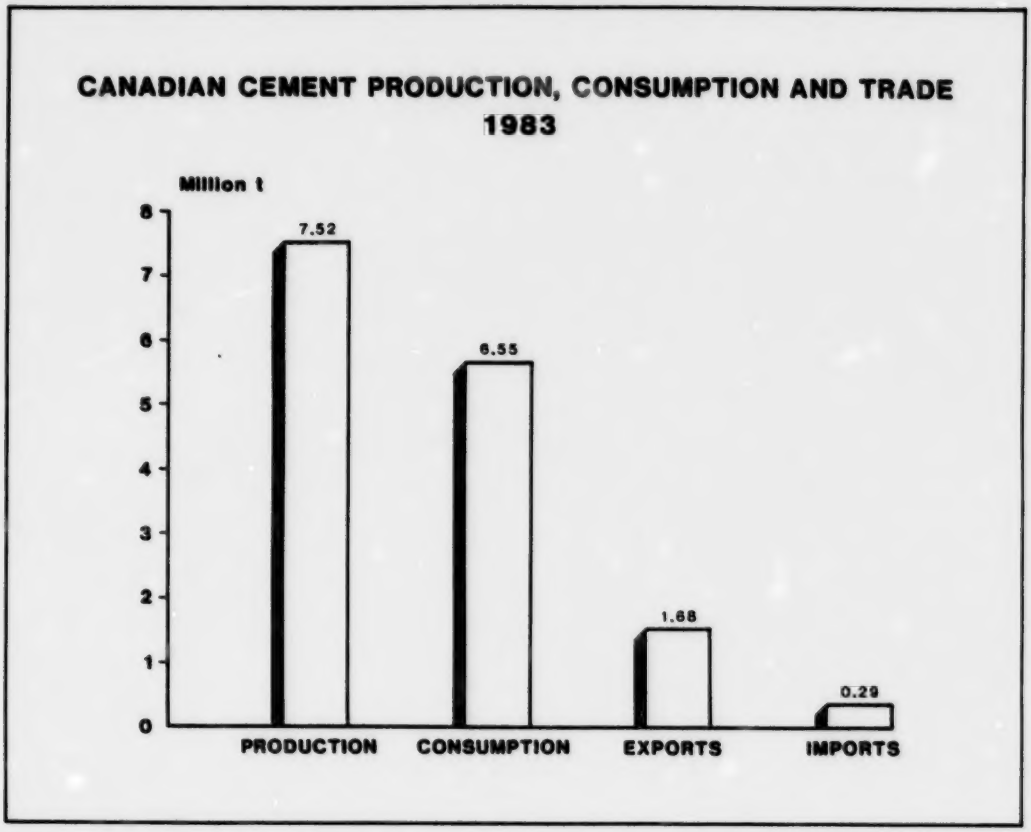
Participating Company

CANADA CEMENT LAFARGE LTD.

Plant Studied

St. Constant, Quebec

Cement: High Specific Power Consumption - High Tonnages



Source: The North American Cement Review, March 1984, Douglas M. Queen, Inc.

Comminution power requirement - Type 10 cement : 76.0 kWh/t.

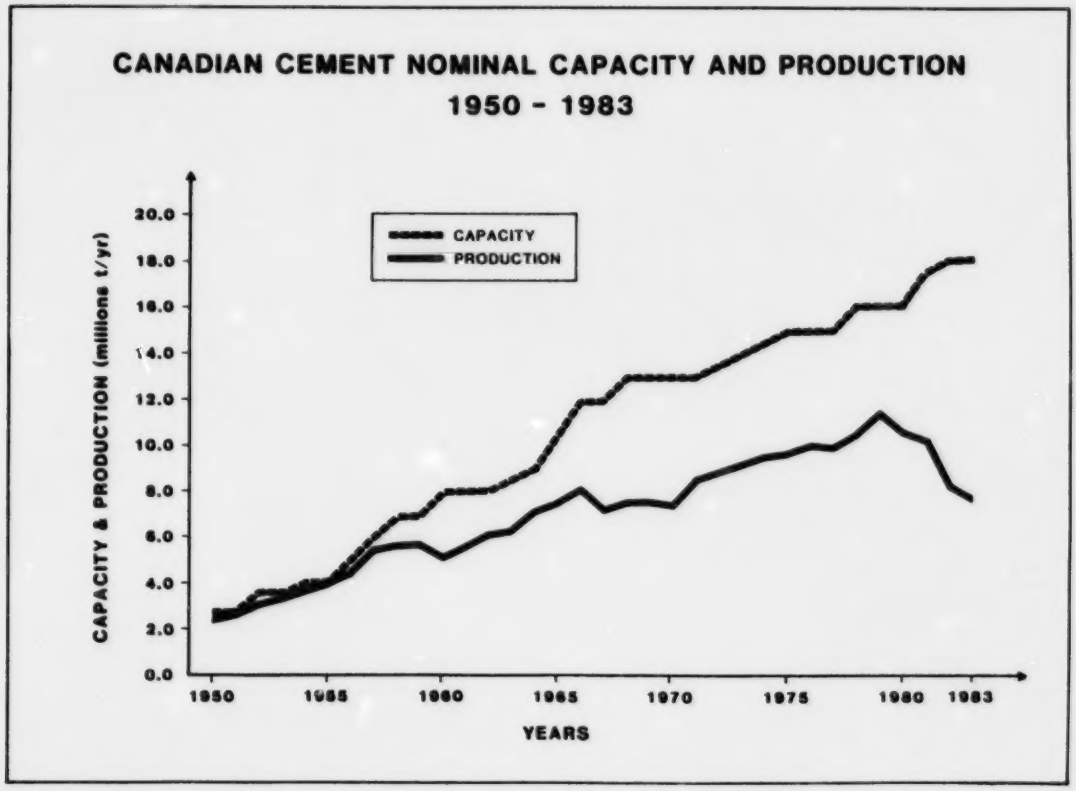
Estimated comminution power requirement by the cement industry in 1983 : 570,000,000 kWh.

Background

The Canadian cement industry has traditionally placed its plants close to markets to minimize distribution costs. The location of Canada's 23 clinker producing plants span the country with at least one in every province, excepting Prince Edward Island.

As of 1983, Canadian cement capacity was approximately 16 million tonnes. The production supplies virtually all the domestic demand. Some cement is exported to northern areas of the United States. Small quantities are imported.

The recession has had a strong impact on cement production. Capacity utilization in 1983 was in the order of 50%. Demand is expected to improve over the next few years when capital spending increases.



Source: Canada Cement Lafarge Ltd.

With the exception of oil well cements, the industry products are used in construction.

CSA CLASSIFICATION OF PORTLAND CEMENTS

NAME	TYPE	APPLICATION
Normal	10	For use in concrete construction when the special properties of the other types are not required.
Moderate	20	For use in general concrete construction exposed to moderate sulphate action, or when moderate heat of hydration is required.
High Early	30	For use when high early strength is required.
Low Heat	40	For use when low heat of hydration is required.
Sulphate-Resistant	50	For use when high sulphate-resistance is required.
Oil Well	58-59	For cementing the casing in place in oil wells.
Masonry	60	For use in bonding brick or concrete block.

The performance of a cement is controlled by a combination of physical and chemical characteristics.

The major chemical components and their typical concentrations in normal portland are as follows:

COMPOUND	INDUSTRY SYMBOL	% OF CLINKER*
Tricalcium Silicate	C_3S	55
Dicalcium Silicate	C_2S	17
Tricalcium Aluminate	C_3A	10
Tetracalcium Aluminoferrite	C_4AF	13
Minor Components		5

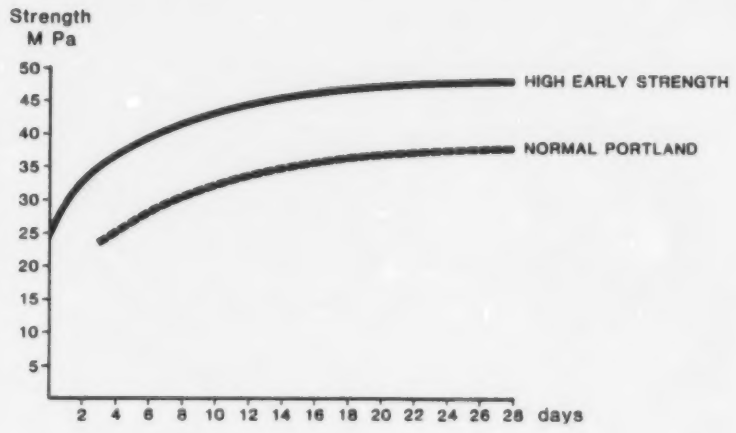
*Clinker as defined on page 33.

Most of the strength of cement is from hydration of the di and tricalcium silicates. The latter contributes to early strength development while the former contributes after about 10 days. The role of tricalcium aluminate and tetracalcium aluminoferrite are not well defined but tricalcium aluminate is believed to be involved in development of early strength.

The most important physical characteristic of cement is its fineness; the more finely ground, the more reactive the cement is; the more reactive, the greater the strength development.

The effect of fineness on compressive strength can be seen by comparing two cements, one with a high fineness and high specific surface area as measured by the Blaine method. This finer cement develops strength more rapidly than the normal product and attains a higher 28 day strength.

DEVELOPMENT OF COMPRESSIVE STRENGTH

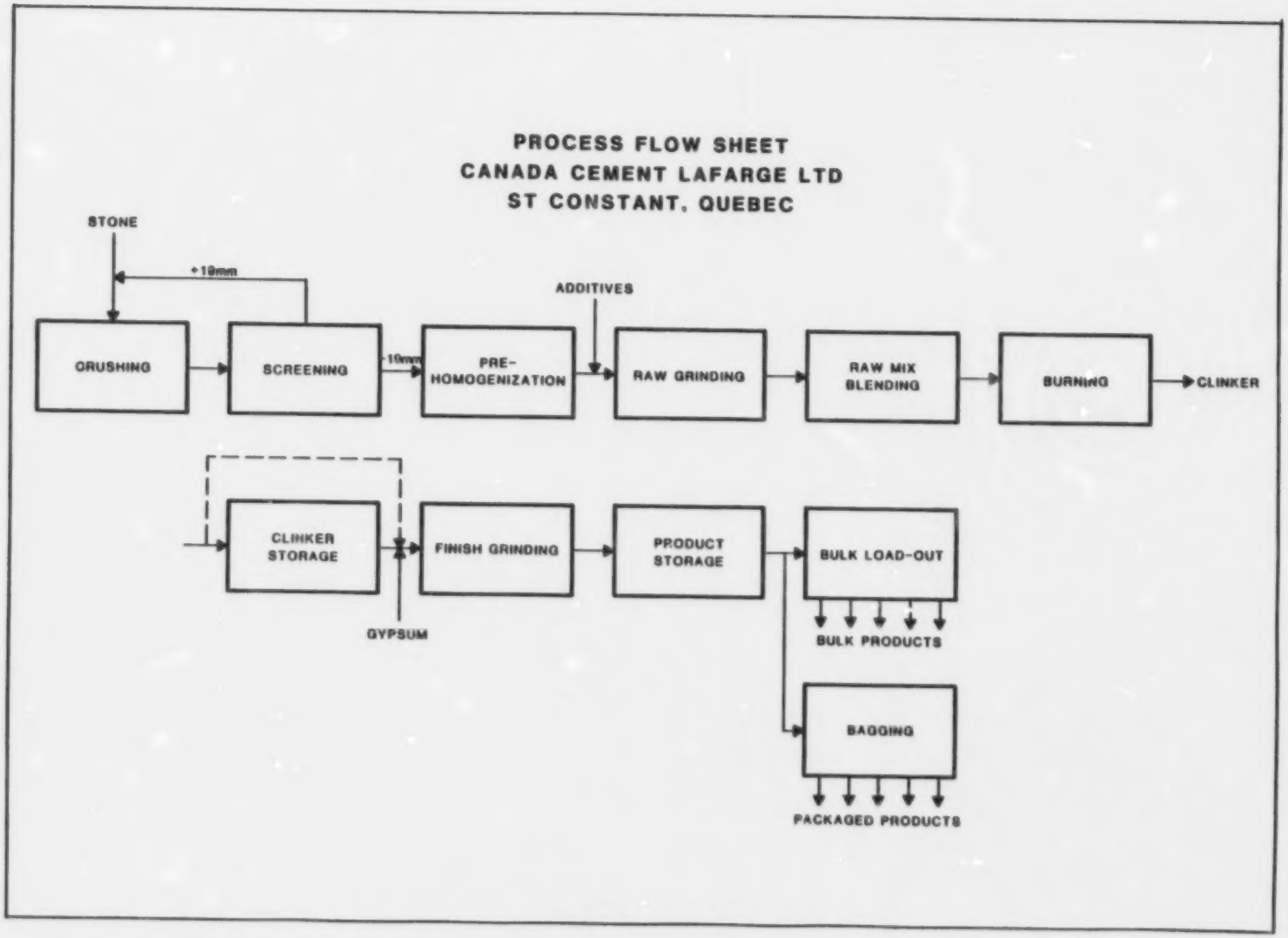


PRODUCT	PASSING 325 MESH %	BLAINE M^2/Kg
NORMAL PORTLAND	90	374
HIGH EARLY STRENGTH	96	550

The Production Process

The manufacture of Portland cement is essentially the production of high calcium silicates from limestones and silicate material such as clay or shale. The reaction is accomplished by pyroprocessing (heat-treating) a very finely-pulverized mixture of the correctly-proportioned quantities of limestone and shale.

The pyroprocessing is done in a sloping kiln, down which the raw feed flows counter-current to a stream of very hot gases from a flame at the lower end. The material leaving the kiln is known as clinker, which is pulverized with a small addition of gypsum to produce the final product - cement. Gypsum is required to control the setting and strength development of the cement when it is mixed with water and mineral aggregates to form mortar or concrete. A typical process flow sheet is shown on page 34.


PROCESS FLOW SHEET
CANADA CEMENT LAFARGE LTD
ST CONSTANT, QUEBEC
STONE
+19mm
ADDITIVES
CRUSHING
SCREENING
-19mm
PRE-
HOMOGENIZATION
RAW GRINDING
RAW MIX
BLENDING
BURNING
CLINKER
CLINKER
STORAGE
FINISH GRINDING
PRODUCT
STORAGE
BULK LOAD-OUT
GYPSUM
BULK PRODUCTS
BAGGING
PACKAGED PRODUCTS

There are two main processes:

- wet, where the raw materials are ground with water to give a slurry, of 30-35% water, which is pumped to the kiln. Because of its thermal inefficiency this process is gradually being phased out;

- dry, where the raw feed is ground and fed to the kiln dry. The St. Constant plant uses the dry process.

Variations of the dry process are the preheater and precalciner technologies, in which the raw material is preheated and precalcined in suspension before entering the kiln.

The pyroprocess by which clinker is formed involves temperatures in the material of up to 1450°C. To achieve this a flame temperature greater than 2700°C is needed. These high temperatures are normally generated by burning gas, oil or pulverized coal.

The Role of Comminution

There are three comminution steps in cement manufacture.

Crushing, where quarried rock is reduced to a size suitable for feeding to the raw mills.

Raw milling, where crushed material is ground to about 80% passing 200 mesh (75 μm) to provide the raw meal for the kiln. The actual degree of fineness at a plant is chosen to optimize the chemical reaction during pyroprocessing. Most installations use ball mills for this stage but roller mills are becoming increasingly popular, particularly in cases where the raw materials are relatively easy to grind.

Finish milling, where clinker is ground, with the addition of about 5% gypsum, to about 85-90% passing 45 µm for Normal Portland (Type 10). The purpose of the fine grinding is to ensure a suitably rapid hydration of the particles in mortar or concrete.

Comminution at the St. Constant Plant

The Crushing Circuit

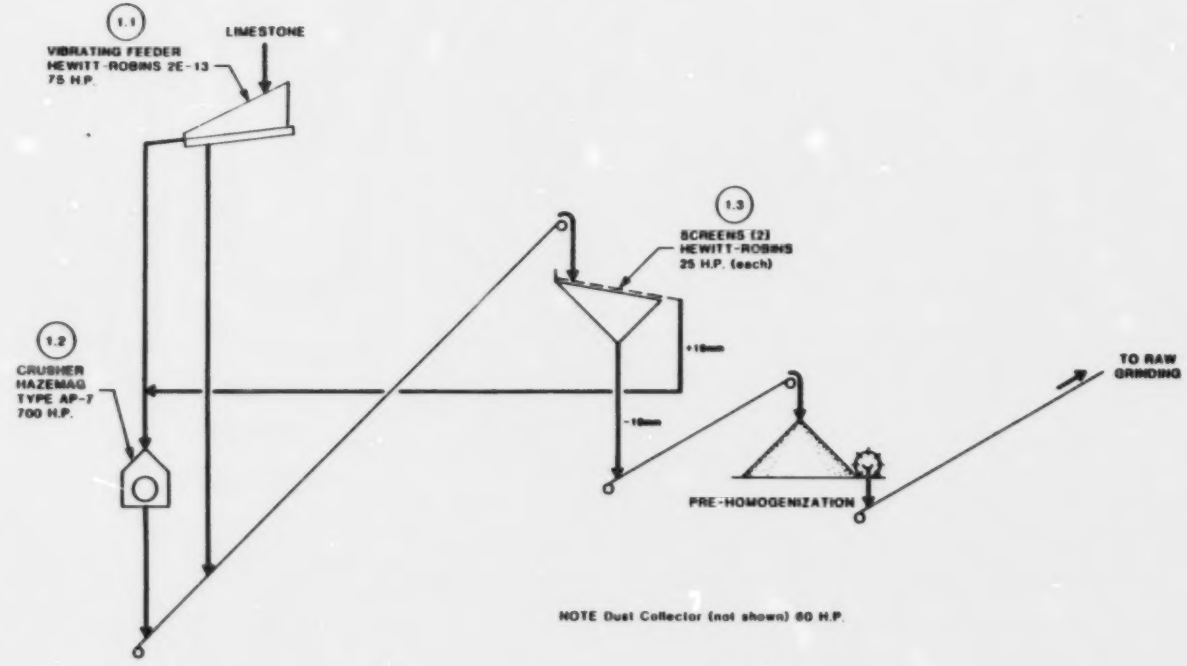
The crushing circuit is shown schematically on page 37. Power levels in kilowatts are summarized on the sketch.

The **flowrate** of the crushing department at the plant varies depending on the moisture content of the quarry-run stone. Experience has shown that the production rate varies from 400 t/h under damp, muddy conditions to 425 t/h under dry conditions. At the time of the plant visit, conditions were wet and the production rate was taken as 400 t/h.

Size distribution. Due to the size of crusher feed, no sample was taken. However, the material was estimated to have the following characteristics:

Maximum size : 1.25 m Average size : 20 cm Minus 4 cm : 30 %	Product : -19 mm

Stone from the crushing circuit is 90-95% of feed to the raw mill.



NOTE Dust Collector (not shown) 60 H.P.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
1-1	FEEDER	46
1-2	CRUSHER	404
1-3	SCREENS - #1	13
	#2	12
1-4	DUST COLLECTOR	54

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 14/12/83	CRUSHING CIRCUIT FLOW DIAGRAM	PLANT CANADA CEMENT LAFARGE ST CONSTANT, QUEBEC
CHECKED DCS DATE 20/09/84		PROJECT No. 20010

The Raw Grinding Circuit

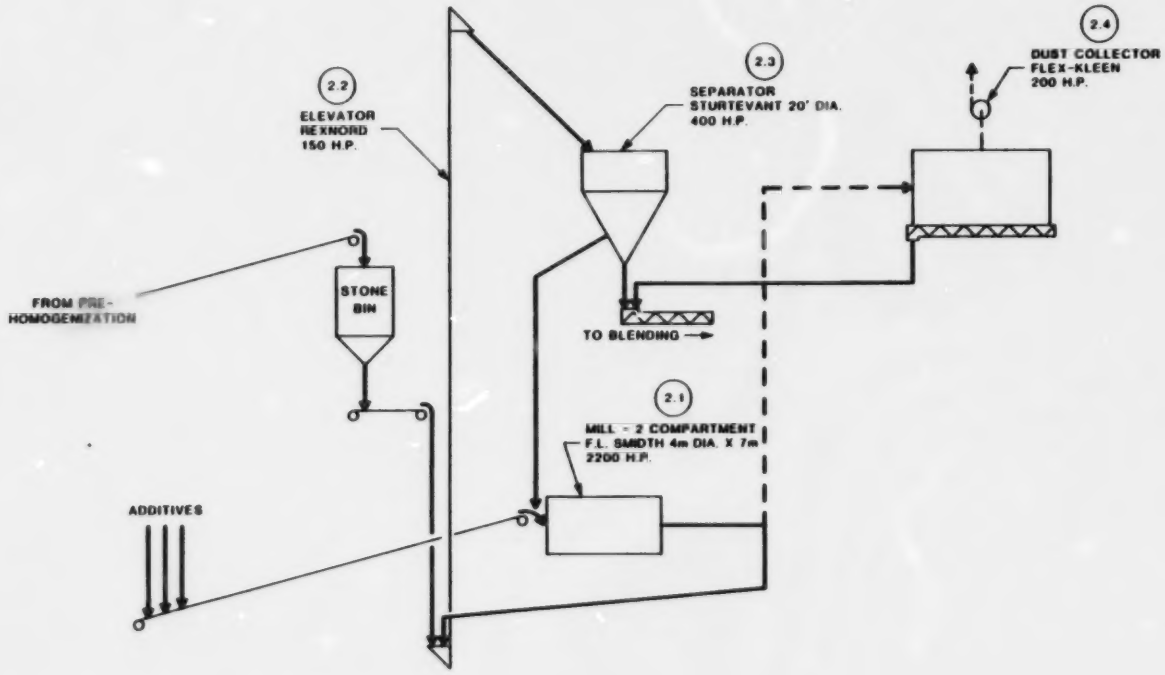
The circuit is shown schematically on page 39. Power levels in kilowatts are summarized on the sketch.

Feedrate. Stone and additive materials are each fed to the mill through separate weigh-feeders. During the period of observation, the feed rate was 116 t/h.

Grindability tests were done on the raw mix components. Coarse sand which makes up 4% or less of the mix is considerably harder to grind than the other components.

Raw Grinding - Measurements

MATERIAL	GRINDABILITY			
	BOND (kWh/Ton)	HARDGROVE INDEX	BOND (CALCULATED)	% OF RAW MIX
Limestone	10.86	60	10.48	90-95
Coarse Sand	20.77	37	16.27	2-4
Fine Sand	-	55	11.34	0.5-1
Iron	-	75	8.55	2



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
2.1	MILL	1635
2.2	ELEVATOR	55
2.3	SEPARATOR	119
2.4	DUST COLLECTOR	93

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 14/12/83
CHECKED DCS DATE 20/09/84

RAW GRINDING CIRCUIT
FLOW DIAGRAM

PLANT CANADA CEMENT LAFARGE ST CONSTANT, QUEBEC

PROJECT No. 20010

Particle size of feed to the mill and product are characterized in the table below.

Raw Grinding of Mill Feed & Product
Size Distribution (% Passing)

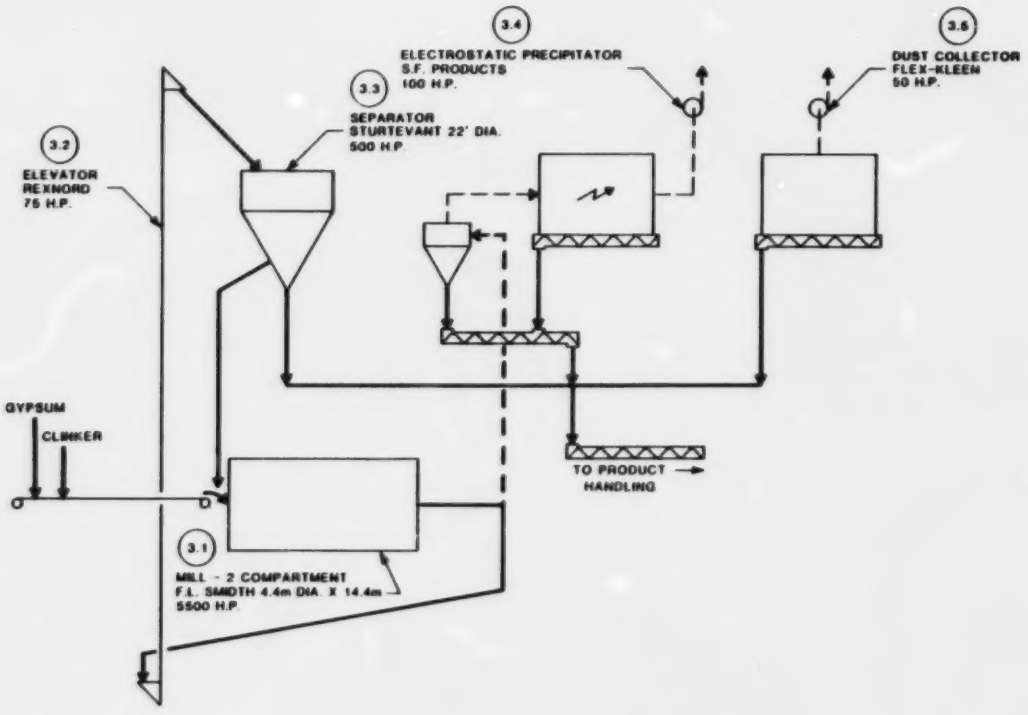
SIZE	STONE	PRODUCT
25.4 mm	100	-
19.0	97.9	-
12.7	81.8	-
9.5	67.7	-
4.75	46.6	-
2.36	32.1	-
1.18	21.7	-
600 µm	14.5	100
300	9.4	99.5
150	5.9	92.7
75	3.6	79.4
45	-	69.6
30	-	62.0
20	-	52.5
10	-	37.0
6	-	27.0
2	-	12.0

Finish Grinding

The circuit is shown schematically on page 41. Power levels are summarized on the sketch.

Flowrate. Clinker and gypsum to the finish mill are metered through individual weighfeeders. The feedrate to the mill was estimated at 95 t/h.

Grindability. Clinker was shown to have a slightly higher grindability than limestone and considerably harder to grind than gypsum.



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
3-1	MILL	4303
3-2	ELEVATOR	50
3-3	SEPARATOR	305
3-4	PRECIPATOR	45
	HIGH VOLTAGE - #1	3
	#2	7
3-5	DUST COLLECTOR	50

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 16/12/83	FINISH GRINDING CIRCUIT FLOW DIAGRAM	PLANT CANADA CEMENT LAFARGE ST CONSTANT, QUEBEC
CHECKED DCB DATE 20/09/84		PROJECT No. 20010

Clinker and Gypsum Grindability

Material	GRINDABILITY		
	Bond (kWh/Ton)	Hardgrove Index	Bond (Calculated)
Clinker	12.01	54	11.54
Gypsum	-	98	6.71

The **particle size** distributions of the feed and product of the finish milling circuit are summarized below.

Finish Grinding
Particle Size Distribution of Mill Feed and Product
(% Passing)

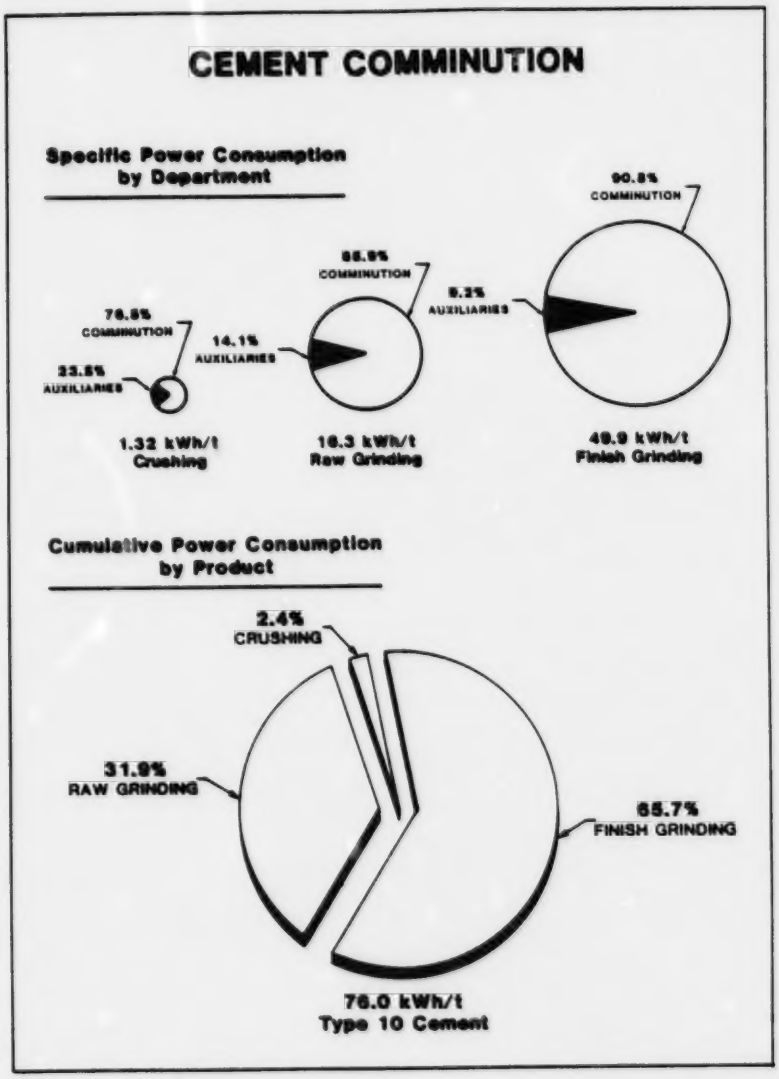
SIZE	FEED	FINISHED PRODUCT
25.4 mm	100	-
19.0	99.1	-
12.7	96.5	-
9.5	93.7	-
4.75	83.3	-
2.36	68.2	-
1.18	55.2	-
600 µm	45.8	-
300	35.9	-
150	19.9	100
75	-	96.7
45	-	85.0
30	-	69.0
20	-	54.0
10	-	34.0
6	-	22.0
2	-	8.0

It is generally accepted that the cement particles between 2 and 45 µm are responsible for strength in concrete. Particles over 45 µm only hydrate superficially and therefore contribute very little. Particles below 2 µm require additional water to coat their surfaces resulting in a higher water/cement ratio and a low contribution to strength.

Thus, 23% of the particles add minimally to the performance of the product.

Results

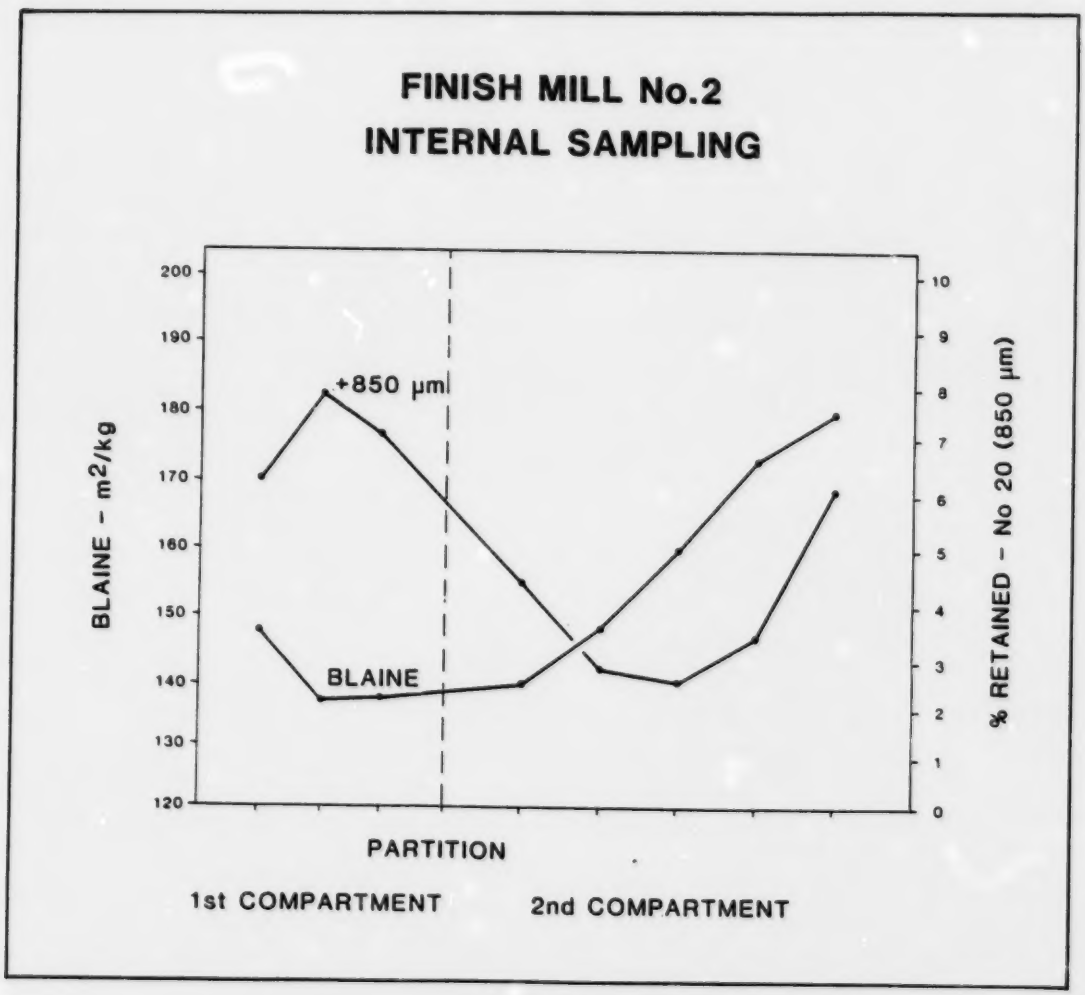
The specific power consumption in the crushing and grinding circuits are summarized in the diagram below.



The higher consumption of the finish grinding circuit can be attributed to both greater fineness of the product and higher bond grindability index of the feed.

The results are believed to be representative of power consumption by the industry as a whole. However, because of the large power demand in finish grinding, a number of checks were run on the degree of optimization of the mill circuit at the plant.

Internal Sampling. The mill was "crash" stopped, and samples were taken to record the passage of fine and coarse material through the two compartments. The results are graphed below.



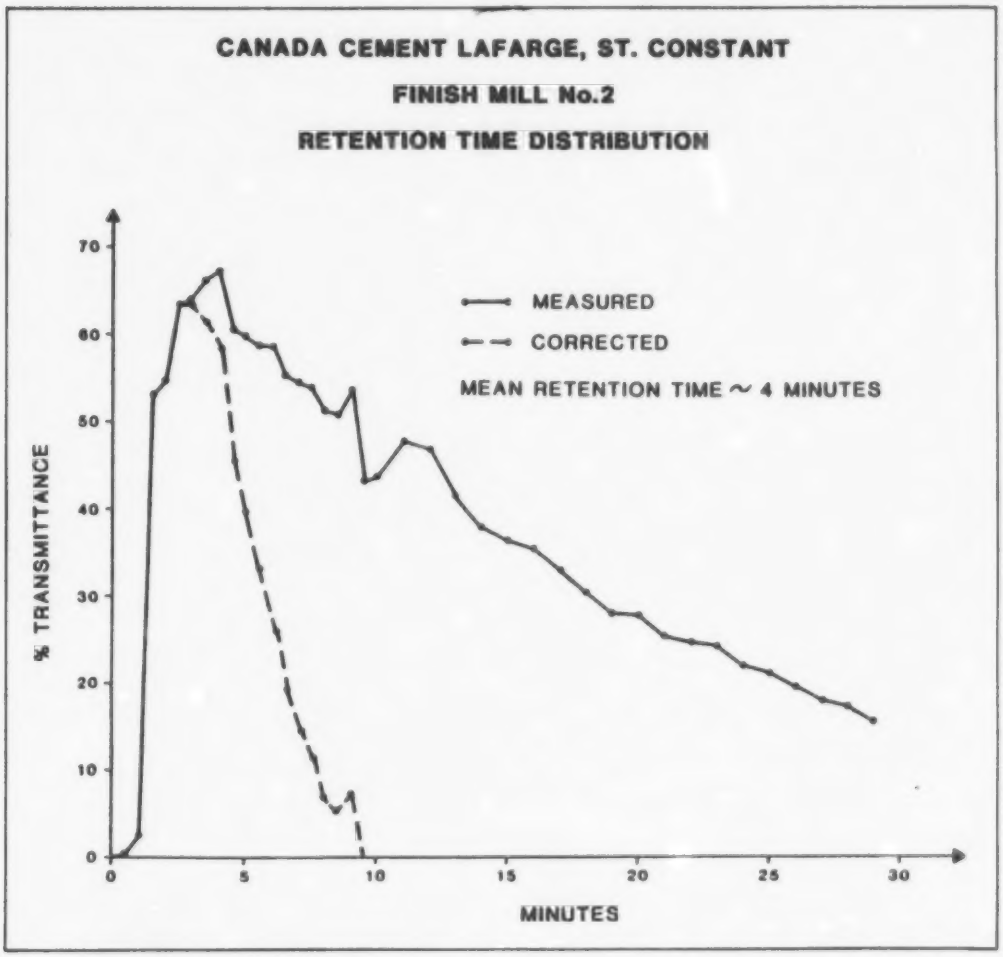
Ideally, grinding of coarse material should occur in the first compartment while generation of fine material should occur in the second. The results show considerable coarse grinding taking place after the partition (+850 μm curve) with a build-up of coarse material near the discharge grates.

The Blaine curve is typical for a two compartment mill. The sample closest to the mill inlet is not considered representative, due to a flush of reject material into the mill from the separator, after the system was "crash" stopped.

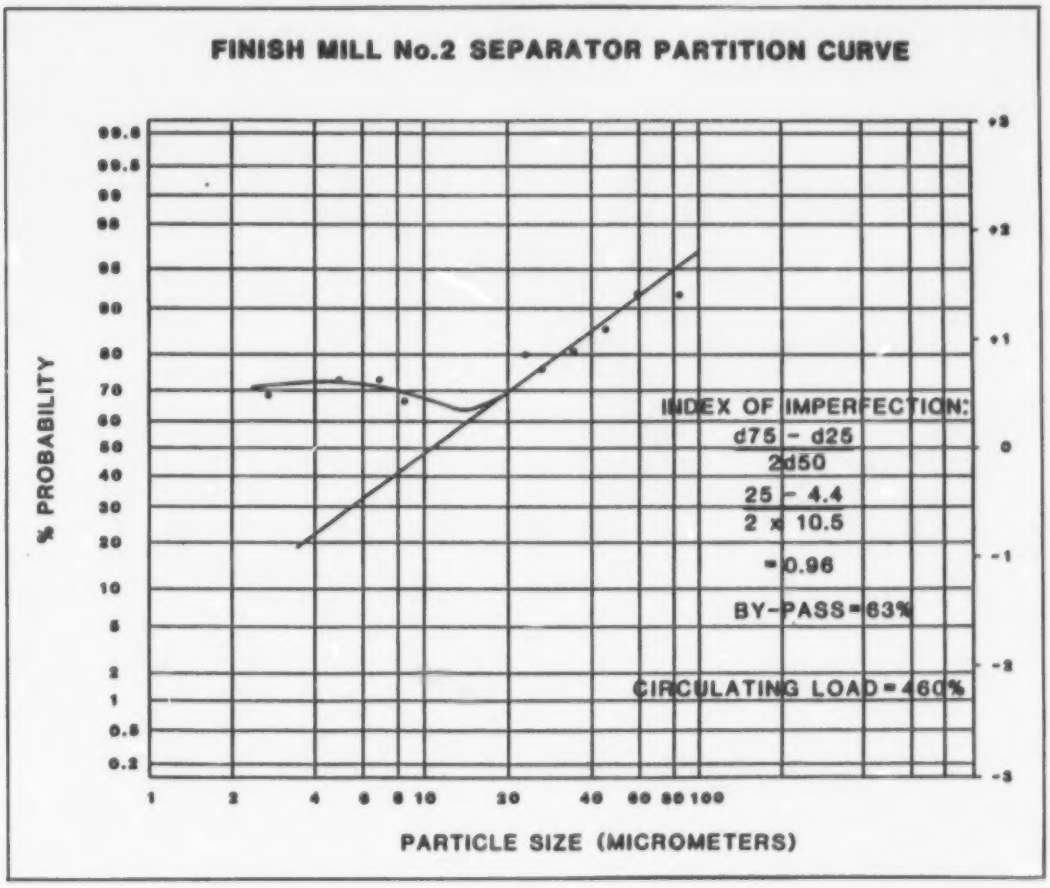
The results indicate a deficiency in the partition allowing excessively coarse material into the second compartment which is not equipped to grind it. Visual inspection of the partition showed some gaps in the grates requiring repairs. The build-up of coarse material in the second compartment is a result of the material being held back by the discharge grates.

Residence time tests confirmed that material was being held up in the mill.

A pulse of dye was put into the inlet of the mill at time zero and the mill discharge was sampled at regular intervals. Dye concentration in the discharge gives retention characteristics of the mill. The theoretical retention time distribution curve corrects for recycle of dye through the reject stream. The resu'ting mean retention time was found to be longer than is usually experienced on this mill.



Air separator performance was checked giving the partition curve shown below.



The partition curve represents the probability of a particle of a given size ending up in the reject stream. The index of imperfection is inversely related to the steepness of the sloped part of the curve. The flat part of the curve is the by-pass where particles have a more or less equal probability of being rejected regardless of size.

The results indicate that separator performance was not optimal; both the index of imperfection and by-pass being high. Internal inspection of the separator revealed repair work needed on selector blades and table. Repairs to finish mill partition and separator are expected to improve separation efficiency, reduce circulating load and specific energy consumption.

Conclusions

The finish milling circuit was not operating under optimal conditions during the test but the overall results nonetheless can be used as a fair representation of power consumption in the comminution stages of cement manufacture.

It is concluded that power consumption could be reduced,

- in the short term, by continued optimizing of existing milling circuits,

- in the medium term, by introduction of improved classification so that the over and undersized particles are eliminated. Up to 25% of finish grinding energy could be saved,

- in the long term, by introduction on new types of mills with better grinding efficiences. The large investment by the industry in conventional mills will tend to retard this approach.

GYPSUM

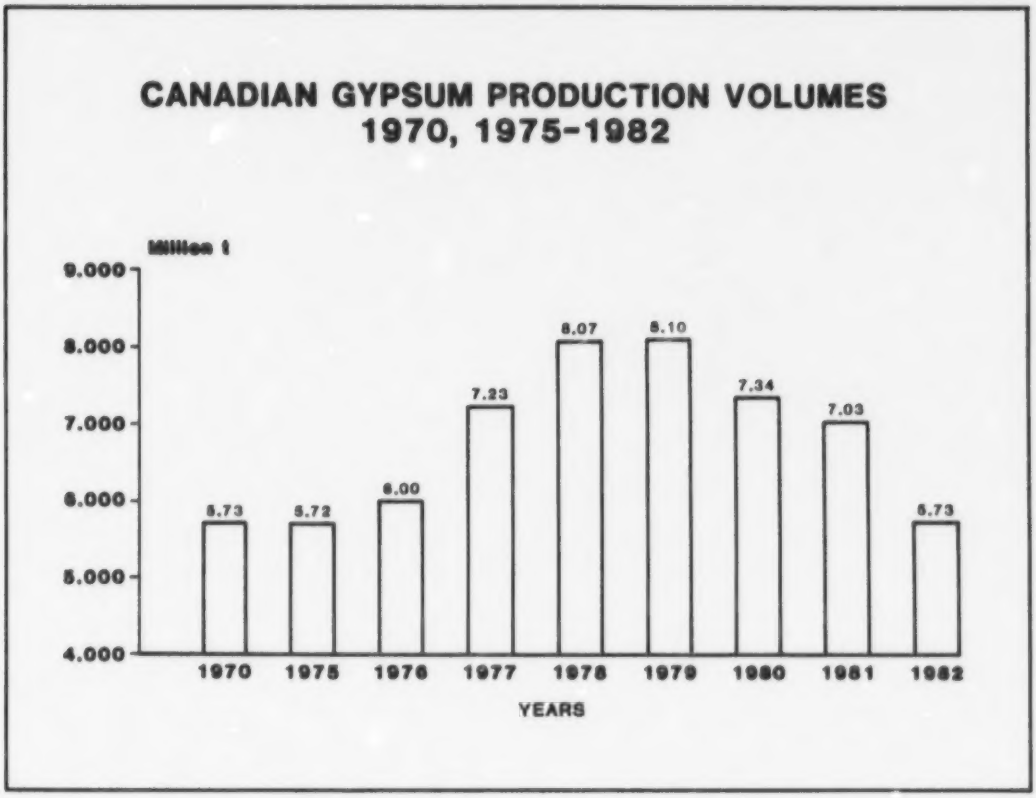
Participating Company

DOMTAR INCORPORATED

Plant Location

Caledonia, Ontario

Gypsum: Low Energy Consumption for Comminution



Source: Canadian Minerals Yearbook 1982, EMR Canada.

Average comminution power requirement : 18.4 kWh/t.

Estimated comminution power requirement by the gypsum industry in 1982 : 45,000,000 kWh.

Background

The principal location of Canada's gypsum industry is the province of Nova Scotia which accounts for about three-quarters of Canadian production. Gypsum products are manufactured in every province except New Brunswick and Prince Edward Island.

Canada is the world's second largest producer, and exports about 70% of its production to the United States as crude gypsum. Imports in the form of wallboard from the U.S. have declined greatly during the last few years. Output of gypsum products is directly linked to construction activity.

Products and Uses

Gypsum has the property of being able to release associated water at relatively low temperatures to form hemi-hydrate and to regain water to form gypsum. During re-hydration, the gypsum "sets" to form an insulating, fire-retardant board, used in building construction.

The main impurities in commercial gypsum are limestone, shale, or clay. The amount of impurities which can be tolerated depends on the type of impurity, and the final product.

The major chemical components of pure gypsum and anhydrite are:

Component	Pure Gypsum	Anhydrite
Combined Water	20.9%	-
Sulphur Trioxide (SO_3)	46.6%	58.8%
Lime (CaO)	32.5%	41.2%

Uses of crude (uncalcined) gypsum include manufacture of Portland cement, where gypsum acts as a retarder to control setting rate, as a filler in paint or paper manufacture, a substitute for salt cake in glass manufacture, and as a soil conditioner.

The Production Process

Gypsum processing involves the reduction of gypsum ore by crushing and grinding and subsequent formation of the hemi-hydrate by calcining. The pyroprocessing is by batch. A charge of crude gypsum is fed into a kettle equipped with an agitator, heated until the material temperature reaches about 160°C and water vapour is driven off to form the hemi-hydrate. The calcined gypsum, called "stucco", can be packaged and sold as a finished product to be used as plaster. Most of the stucco, however, is used to make gypsum board. A slurry of stucco and water is prepared and immediately placed between two layers of paper in a continuous process. The gypsum "sets" rapidly and the board is cut, dried, and palletized in preparation for shipment as finished product. A typical process flow sheet is shown overleaf.

The Role of Comminution

There are two comminution steps in the gypsum process.

Crushing, where mined ore is reduced to a size suitable for feeding to the mill. The crushed ore is also dried of surface moisture.

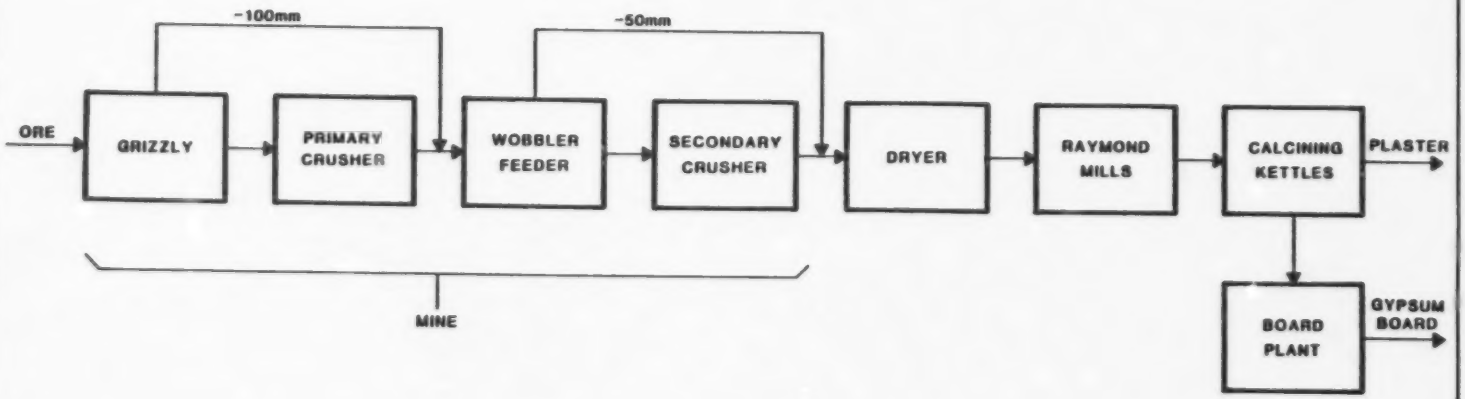
Milling, where crushed material is reduced to about 95% minus 150 μm for feeding to the calcining kettles.

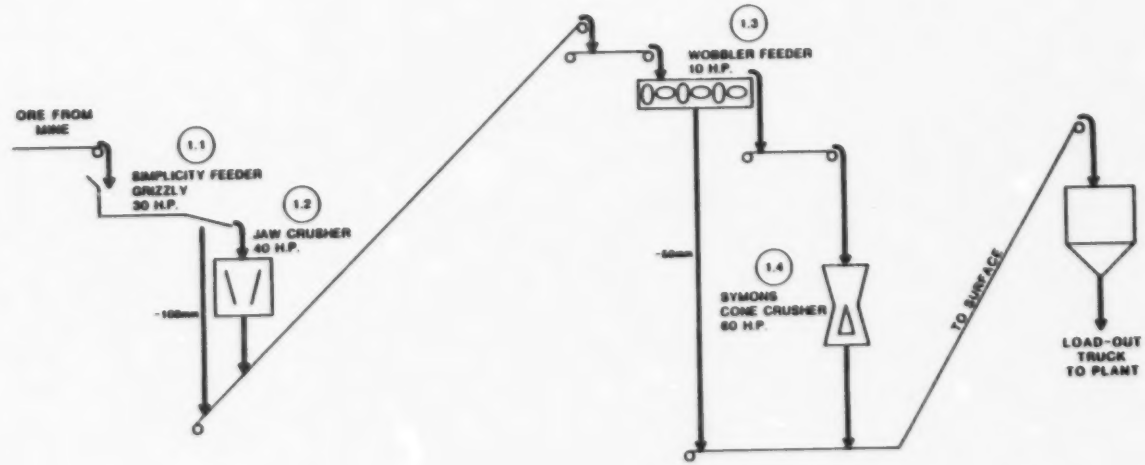
Comminution at the Caledonia Plant

The Crushing Circuit

The crushing circuit is shown schematically on page 53. Rated power (HP) and average demand (kW) in operation are summarized on the sketch.

PROCESS FLOW SHEET
DOMTAR GYPSUM DIVISION
CALEDONIA, ONTARIO





NOTE: Aspiration Fan (not shown) 10 H.P.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
1.1	Simplicity Feeder	8.5
1.2	Jaw Crusher	10.1
1.3	Wobbler Feeder	2.1
1.4	Cone Crusher	29.7
1.5	Aspiration Fan	10.4

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 01/09/84	GYPSUM CRUSHING FLOW DIAGRAM	PLANT CONSTRUCTION MATERIALS DOMTAR-CALEDONIA, ONT.
CHECKED DCB DATE 20/09/84		PROJECT No. 20010

The **production rate,** at the time power demand measurements were taken, was 210 t/h.

Size distribution. Ore feed to the crushing circuit was estimated to be minus 300 mm with most of the material being minus 150 mm. The circuit product was minus 75 mm.

The **Hardgrove grindability** index was determined to be 61 with a calculated Bond Work Index of 10.32 kWh/Ton.

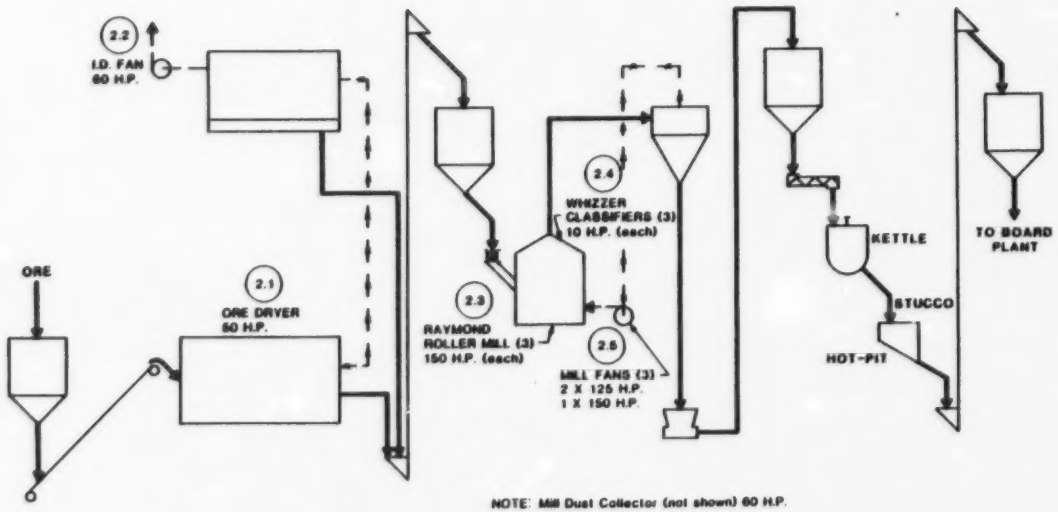
The Grinding Circuit

The circuit is shown schematically on page 55. Rated power and average demand are summarized on the sketch.

Flowrate. The circuit is made up of 3 mills operating in parallel. The combined production rate of the circuit was 41 t/h.

Size distribution. Feed to the mills and circuit product is characterized in the table below.

	% Passing	
Size	Feed	Product
75 mm	100	
50	90.5	
25	61.9	
12.5	40.0	
1.18	11.4	
425 µm		100
150	3.8	93.0
106		84.5
75		78.3
45		75.5
20		63.0
10		48.0
2		13.5



NOTE: Mill Dust Collector (not shown) 60 H.P.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
2-1	Dryer	21.7
2-2	I.D. Fan	26.3
2-3	Raymond Mill #1	135
	#2	118
	#3	115
2-4	Whizzer #1	5.7
	#2	3.3
	#3	4.5
2-5	Fan #1	95.2
	#2	96.3
	#3	103
2-6	Dust Collector	17.6

CANADA CEMENT LAFARGE LTD.
MONTREAL

Drawn FGM Date 08/09/84
Checked DCG Date 20/09/84

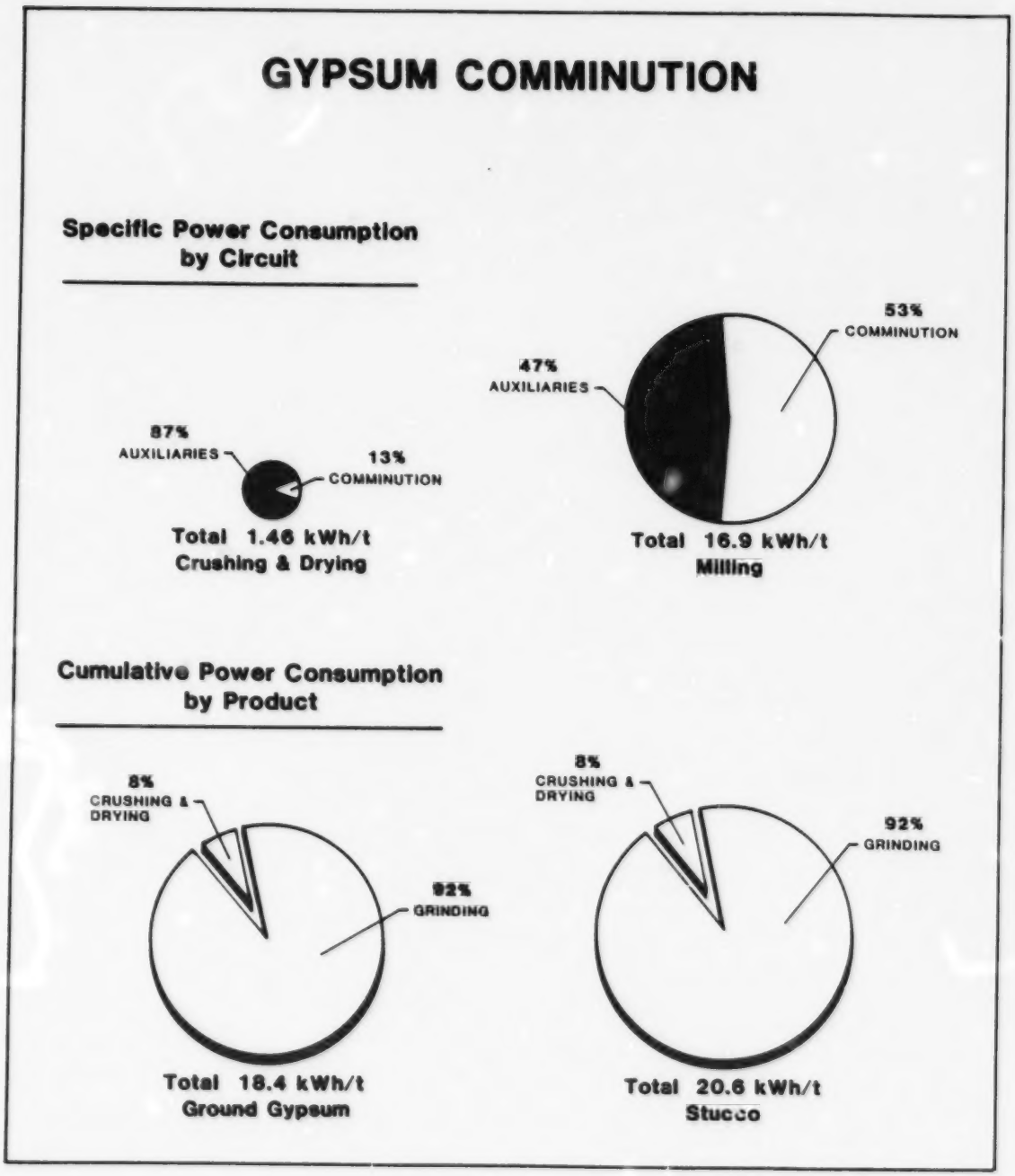
GYPSUM GRINDING + CALCINING
FLOW DIAGRAM

Plant CONSTRUCTION MATERIALS
DONTAR-CALEDONIA, ONT.

PROJECT No. 20010

Results

The specific power consumption in the crushing and grinding circuits is summarized as follows:



Energy consumption by comminution and associated operations in the gypsum process is relatively low compared to other industrial minerals. This is due to the low grindability index of gypsum and the coarseness of the ground product.

Cumulative specific consumption for stucco accounts for a yield factor of 89% in the calcination step due to water loss.

Conclusions

Comminution, itself, accounts for a relatively small proportion of consumption for crushing and drying. The two crusher motors are not heavily loaded. Auxiliary energy demand includes consumption by dryer drive and draft fan.

Milling consumption is about evenly divided between comminution and auxiliaries. Despite the fineness target of 95% passing 150 μm, nearly half the mill product was determined to be minus 10 μm. This over grinding may be a result of high circulating load which is evidenced by the heavy loading of the fan motors. However, plant experiments have shown the best production rate with both mill and fan motors running at capacity. A roller mill does not seem to be the most suited milling equipment.

The results were obtained under typical plant operating conditions and are believed to be representative of the industry.

Recommendations

None.

LIME

Participating Company

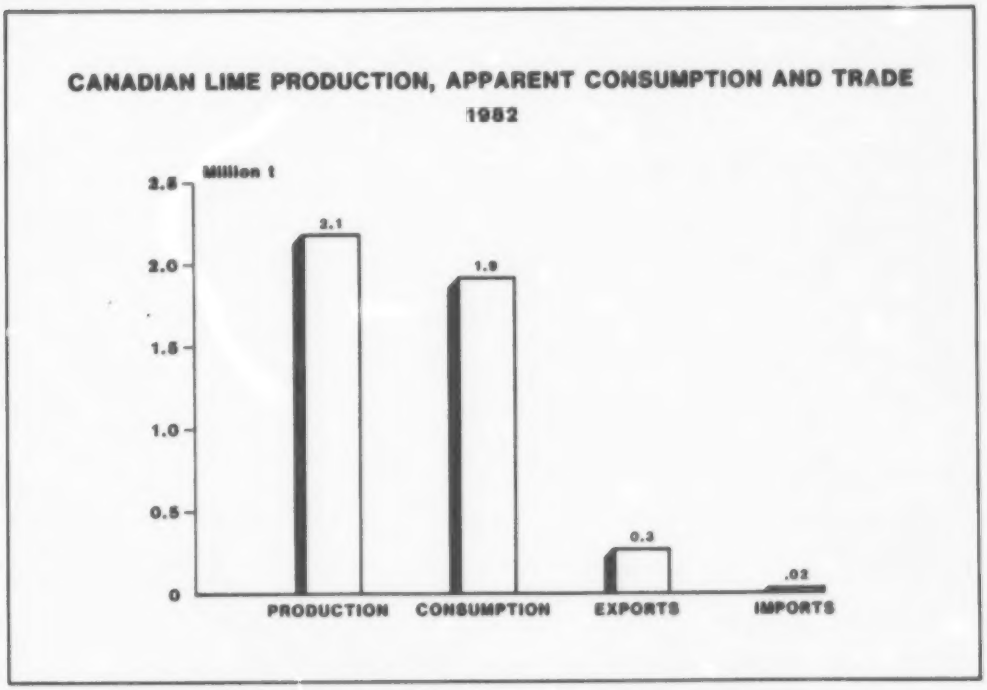
DOMTAR INCORPORATED *

Plant Location

Joliette, Quebec

* Joliette plant now owned by Jolichaux Inc.

Lime: Low Specific Power Consumption - Large Tonnages



Source: Canadian Minerals Yearbook 1982, EMR Canada.

Average comminution power requirement* : **2.8 kWh/t.**

Estimated comminution power requirement by the lime industry in 1982 : **6,000,000 kWh.**

Background

Lime is a high-bulk, low-cost commodity. Thus, plants are generally located close to markets and adjacent to a source of suitable limestone. The industrialized provinces, Ontario and Quebec, together produce about 80% of Canadian lime output.

* Assuming that steelworks lime is 50% of industry production.

The production figures shown below do not include captive capacity, of pulp and paper plants, which burn sludge to recover lime for re-use.

Canadian lime capacity is estimated to be about 3-5 million tonnes per year. Current demand is considerably below this level because of current economic conditions.

Lime, as shown in the table below, has a wide range of applications.

Canada, Consumption of Lime, Quick and Hydrated, 1981 (Producers' Shipments and Quantities Used by Producers, By Use)

	1981P	
	(tonnes)	%
Chemical and metallurgical		
Iron and steel plants	1 237 519	48.5
Pulp and paper mills	271 945	10.6
Water and sewage treatment	22 760	
Nonferrous smelters	117 632	6.5
Cyanide and flotation mills	(4)	
Sugar refineries	25 841	
Other industrial	690 040	27.0
Agricultural	17 370	
Road stabilization	9 338	7.4
Other uses	162 555	
Total	2 555 000	100.0

Source: Statistics Canada; Energy, Mines and Resources, Canada.

Steel-making lime specifications require a low sulphur content, generally below 0.1%. Typical particle size range for this product is between 50 and 5 mm.

Lime sold for other uses normally has a maximum permissible sulphur level and a particle size specified to match the chemical reactvity required by the user.

Hydrated lime which accounts for less than 10% of production is mainly used in water treatment by smaller scale consumers who do not have slaking equipment.

The Production Process

A general process flow sheet for lime manufacture is illustrated. Lime manufacture can be simplified into three basic steps:

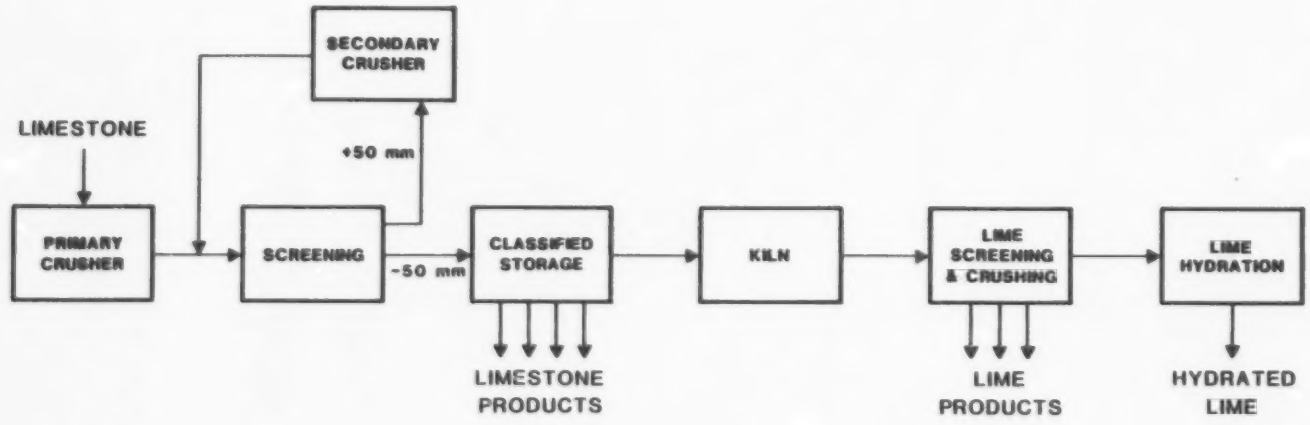
- Stone preparation (kiln feed).
- Calcination.
- Lime hydration.

Hydrated lime production requires additional process steps:

- crushing the quicklime,
- mixing the quicklime with water,
- removal of impurities and uncalcined limestone by air classification.

LIME PROCESS FLOW SHEET

DOMTAR JOLIETTE PLANT



STONE PREPARATION | CALCINATION | HYDRATION

The Role of Comminution

There are two comminution stages in lime manufacture and both involve crushing.

Limestone crushing, where the quarried rock is reduced to a suitable size for kiln feed, which is made up of given proportions of different sizes of limestone from classified storage. The size of the feed determines the size distribution of the quicklime after calcination.

Lime crushing, where the purpose is to reduce the quicklime to the particle size specified by consumers or to prepare it for hydration.

Comminution at the Joliette Plant

The Limestone Crushing Circuit

The circuit is shown schematically on page 63 with power demand in kilowatts summarized on the sketch.

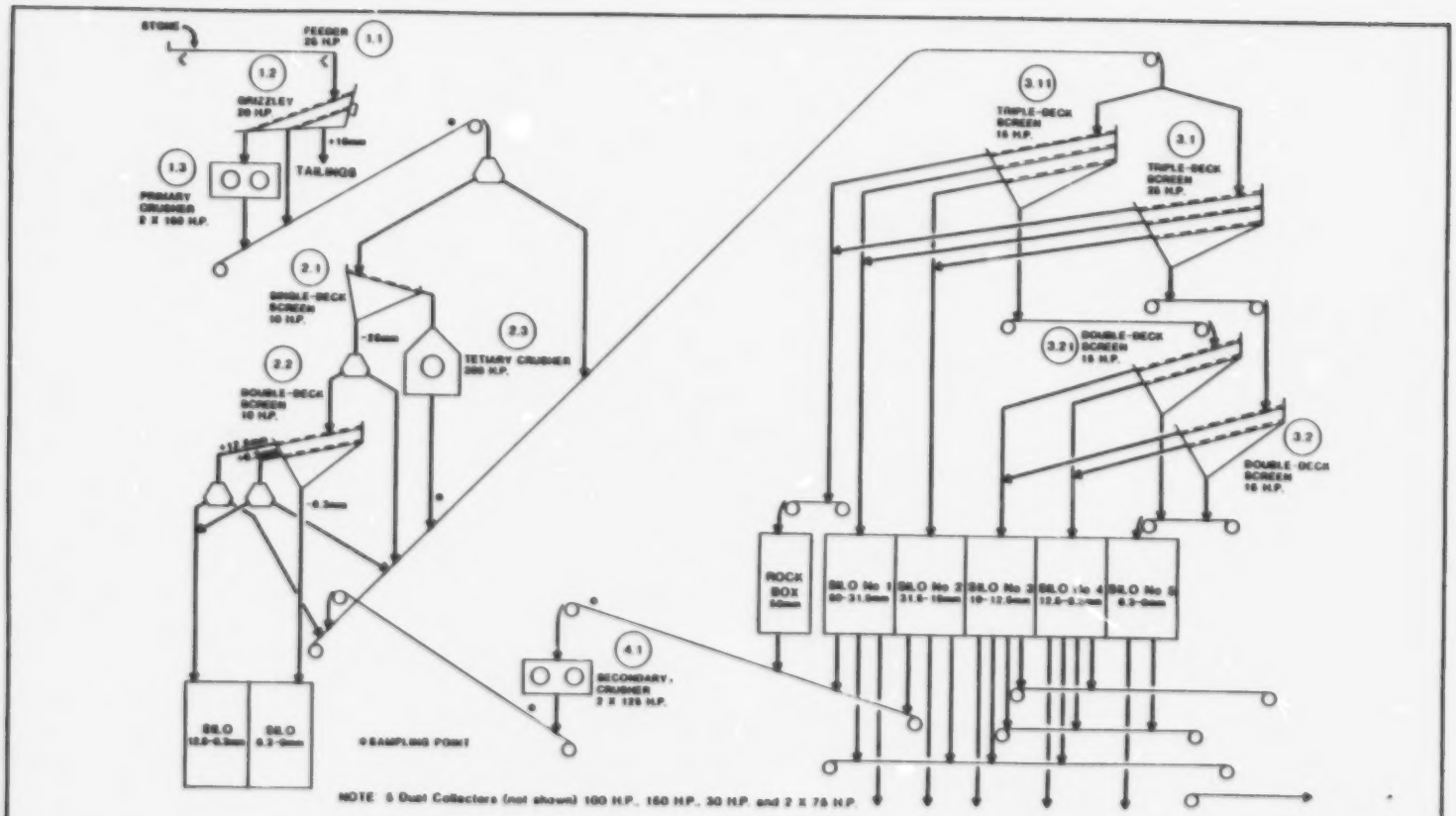
The circuit is used in production of limestone products as well as kiln feed.

The **flowrate,** at the primary crusher, of 493 t/h was estimated from a quarry truckload count.

Flowrate to the secondary crusher was estimated to be 152 t/h.

Grindability tests showed the limestone to have a Hardgrove Index (HGI) of 83 and a Bond Index of 8.86 kWh/ton.

A typical HGI for limestone is in the range 50-70, giving an average calculated Bond Index of 10.48 kWh/ton.



NOTE 6 Dust Collectors (not shown) 100 H.P., 150 H.P., 30 H.P. and 2 X 75 H.P.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
1.1	Feeder	2
1.2	Grizzley	8
1.3	Primary Crusher	90
1.4	Dust Collector	122
2.1	Dust Collector	51
2.2	Tert. Crusher Dust Collector	52
3.11	Triple-Deck Screen	6.9
3.1	Triple-Deck Screen	6.7

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
3.2	Double-Deck Screen	4.5
3.21	Double-Deck Screen	4.5
3.3	Dust Collector (Screens)	52
3.4	Dust Collector (Conveyors)	11.4
4.1	Secondary Crusher	18
4.2	Dust Collector	26

CANADA CEMENT LAFARGE LTD.
MONTREAL

Drawn FGN Date 20/04/84	LIMESTONE CRUSHING & SCREENING FLOW DIAGRAM	Plant of PRODUITS CHIMIQUES DOMTAR - JOLIETTE, P.Q.
Checked DCG Date 20/09/84		PROJECT No. 20010

Size distribution. Crusher feed size range was minus 1250 mm, plus 150 mm. Most of the material was between 600 mm and 300 mm.

The primary crusher product was not sampled directly but was derived from an approximate material balance of the circuit.

PRIMARY CRUSHER PRODUCT SIZE DISTRIBUTION	
mm	% passing
150	100
100	94
50	72
25	45
12.5	25
6.3	12

The secondary crusher feed and product size distributions were both sampled. The following table summarizes the size distributions.

SECONDARY CRUSHER FEED AND PRODUCT SIZE DISTRIBUTIONS		
mm	% feed passing	% product passing
132.5	100	
100	80	
75	60	100
50	13	87
38.1	3	79
25		58
19		46
12.5		31
9.5		24

Crushing circuit product size distribution is as follows.

CIRCUIT PRODUCT SIZE DISTRIBUTION	
mm	% passing
50	100
31.5	86
19	64
12.5	41
6.3	20

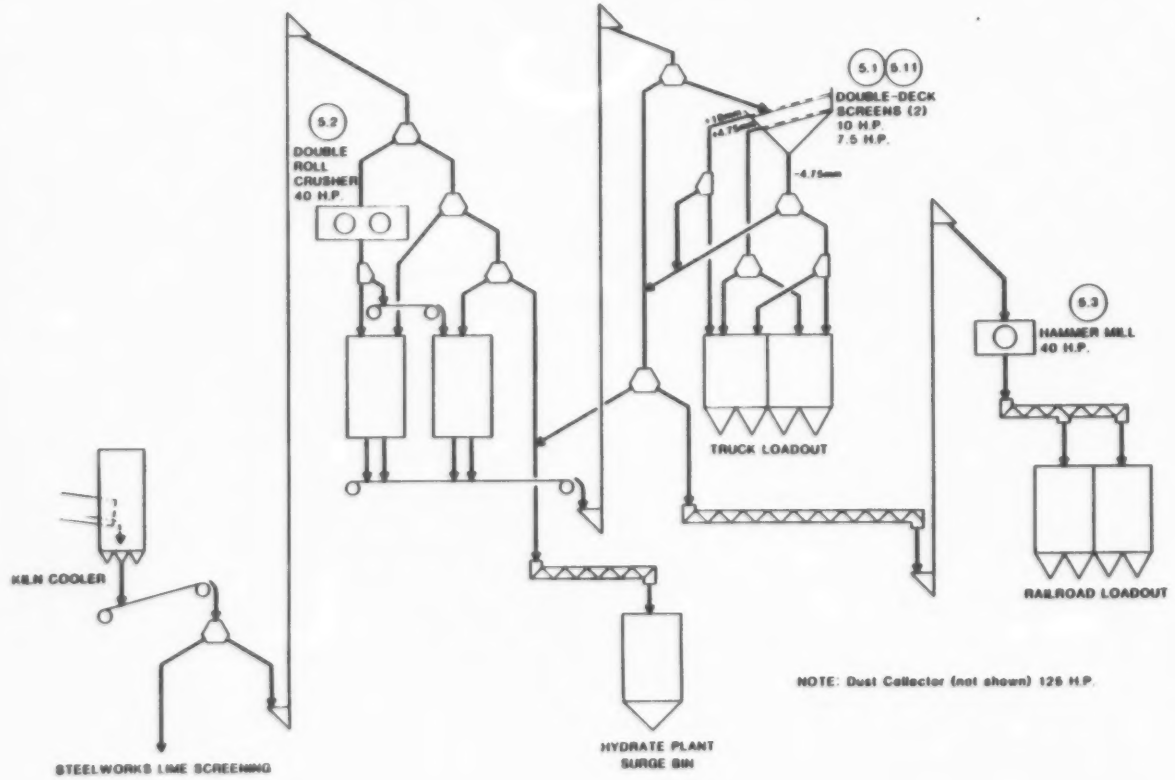
Lime Crushing Circuits

The essential steps of lime processing are shown in the accompanying flow diagrams. One product, steelworks lime, does not require crushing but is screened to remove fines. The other products, 3/16 inch lime and hydrated lime are both crushed.

The **flowrates** through the systems are summarized.

LIME FLOWRATES	
PROCESS UNIT	t/h
Raw Lime Screening	14.5
3/16 Inch Lime Crushing	8.5
Steelworks Lime - 1st Screening	16.8
Steelworks Lime - 2nd Screening	136
Hydrate Plant	14.5

Grindability tests on lime by both the Hardgrove and Bond procedures were conducted. The test results, as expected, show lime to be extremely easy to grind. The Hardgrove Index (HGI) was determined to be 165. The Bond test gave a value of 4.2 kWh per short ton.



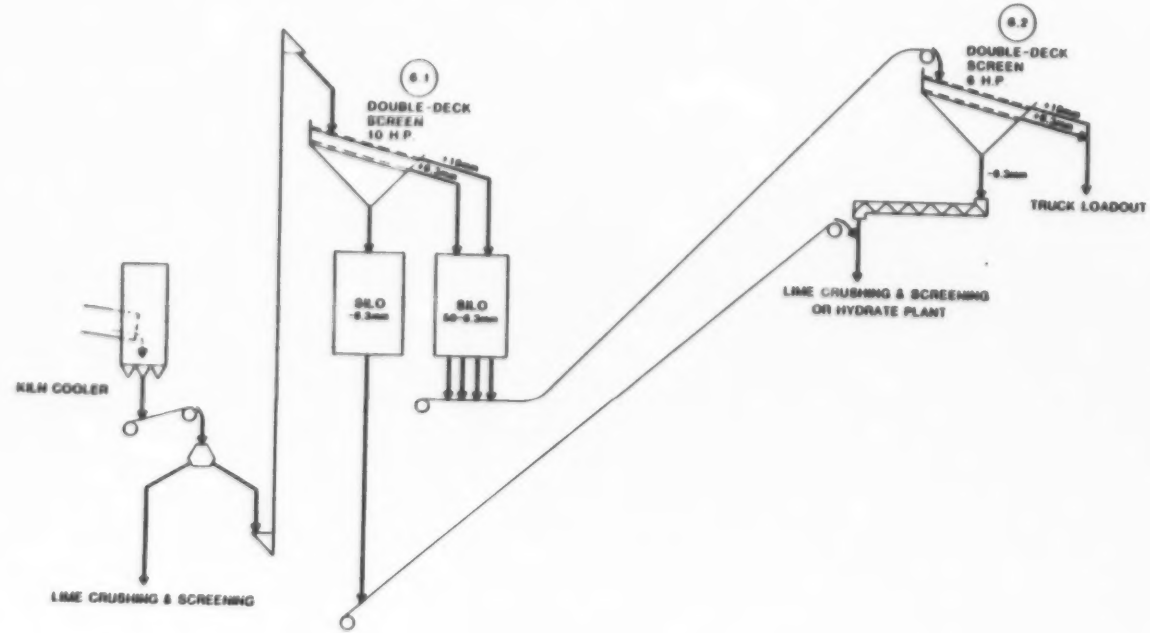
POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
5.1	Double-Deck Screen	3.2
5.11	Double-Deck Screen	3.5
5.2	Double Roll Crusher	4.5
5.3	Hammer Mill	7.0
5.4	Dust Collector	70.0

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 21/04/82
CHECKED DCS DATE 20/09/84

LIME CRUSHING & SCREENING
FLOW DIAGRAM

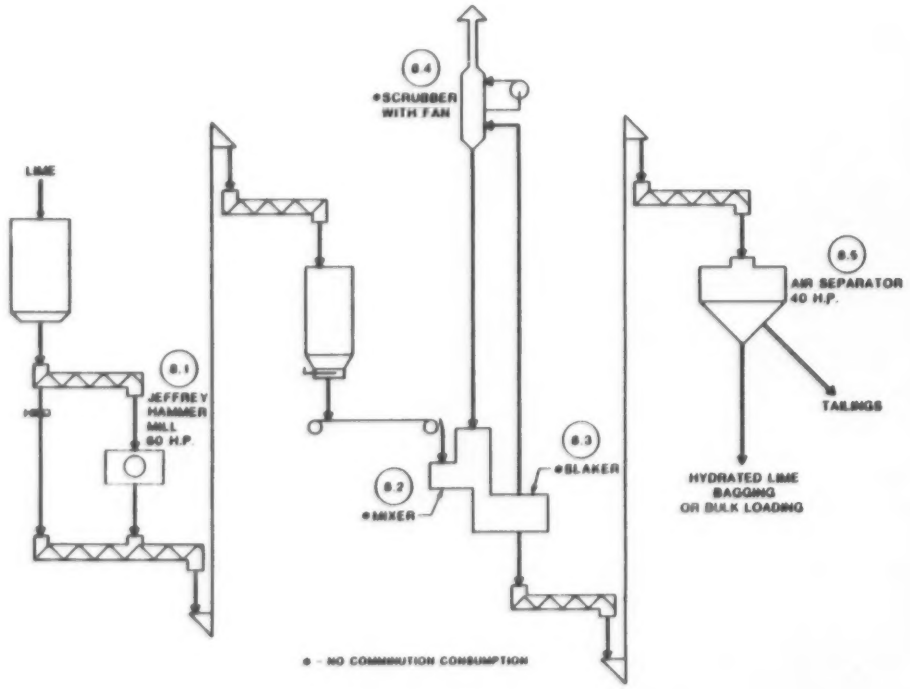
PLANT OF PRODUITS CHIMIQUES DOMTAR - JOLIETTE, P.Q.
PROJECT No. 20010



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
6.1	Double-Deck Screen	3.0
6.2	Double-Deck Screen	3.5

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 21/04/89	STEELWORKS LIME SCREENING FLOW DIAGRAM	PLANT PRODUITS CHIMIQUES DOMTAR - JOLIETTE, P.Q.
CHECKED DCB DATE 20/09/84		PROJECT No. 20010



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
8.1	HAMMER MILL	14.0
8.2	MIXER	-
8.3	SLAKER	-
8.4	SCRUBBER WITH FAN	-
8.5	AIR SEPARATOR	15.6

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 20/09/84	HYDRATED LIME PLANT FLOW DIAGRAM	PLANT OF PRODUITS CHIMIQUES DOMTAR - JOLIETTE, P.Q.
CHECKED DCS DATE 20/09/84		PROJECT No. 20010

Size distribution. Crushing is used to produce minus 4.75 mm (3/16") lime and also in preparation of lime for hydration.

In the production of minus 4.75 mm lime, the feed to the crusher consists of two thirds of a plus 19 mm fraction and one third of a minus 4.75 mm fraction. This feed results from the screening of raw lime whereby the mid-fraction is extracted and sold as a product.

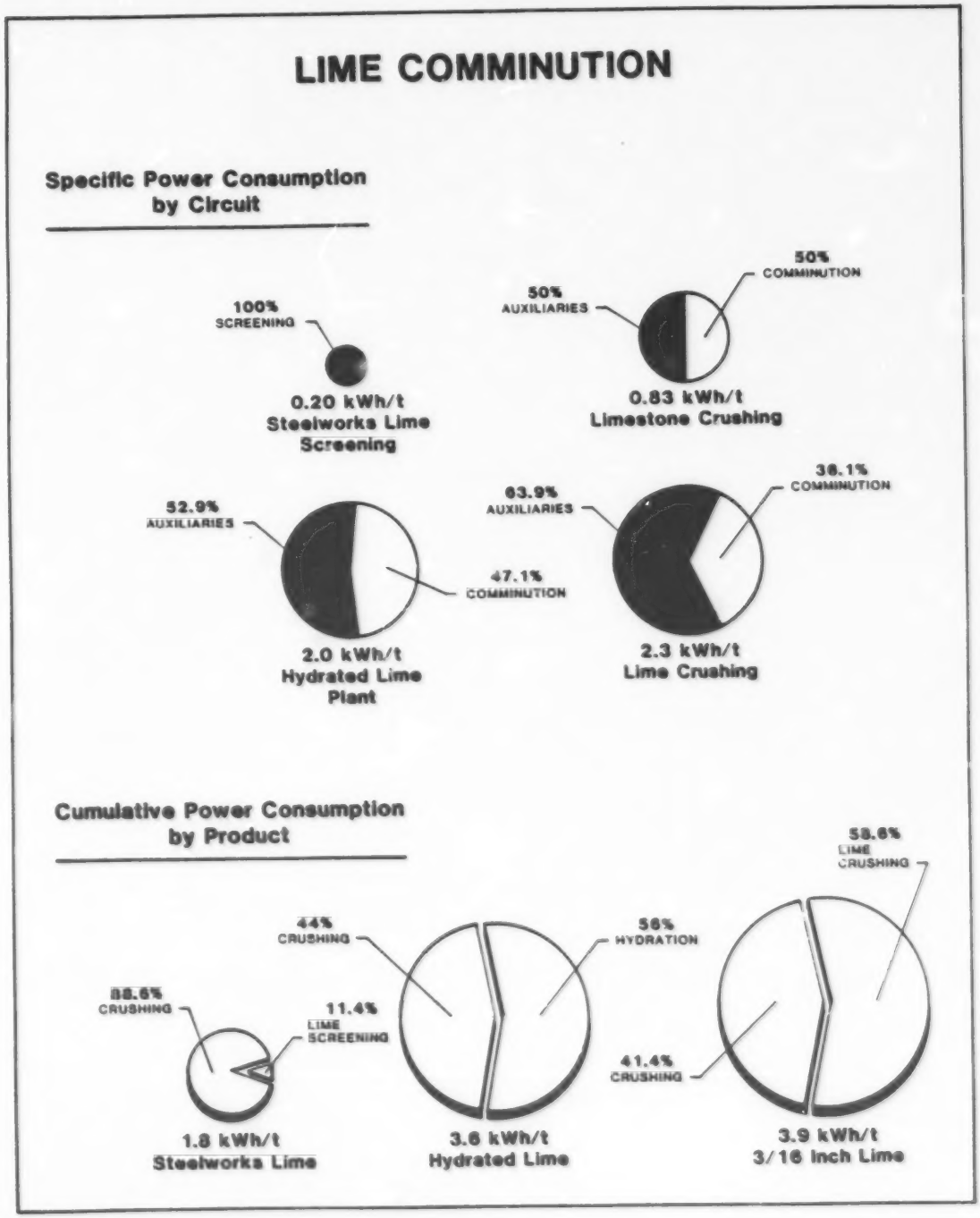
The crushed product had the following size distribution:

3/16 INCH LIME SIZE DISTRIBUTION	
Size (mm)	% Passing
6.70	100
4.75	95
2.36	80
1.18	65
0.60	45

For lime used for hydration, the feed to the crusher can be a raw kiln product, a screened fraction or fines recuperated from dust collection. The fineness of the crushed lime is minus 2.36 mm.

Results

The specific power consumption by circuit and by product, as shown in the diagram below, emphasize the small amounts of power required in comminution.



From plant records, total power consumption was estimated to average 31 kWh/tonne of product. Assuming 3 kWh/tonne, comminution including auxiliaries represents about 10% of the total electric power consumption.

Savings could be had by reducing air flows through the dust collectors when the crushers are idling. A system could be engineered that would automatically close down dampers during idle periods. This would reduce power demand on fan motors for an appreciable amount of time.

Conclusions

The average power consumption for comminution per tonne, including auxiliaries, in the lime industry is low; just under 4 kWh. Moreover, a large part of the calcined product does not require crushing but only screening to remove fines (steelworks lime).

In summary, there appears to be no great potential for electrical energy savings in the lime industry. But the study has brought out the importance of the power consumption attributable to air pollution control. This was established clearly in limestone crushing and screening where dust collection accounts for 42% of total power consumption.

Recommendation

Significant comminution energy savings would be difficult to achieve for this mineral due to the low consumption.

LIMESTONE

Participating Companies

DOMTAR INCORPORATED *

Plant Location

Joliette, Quebec

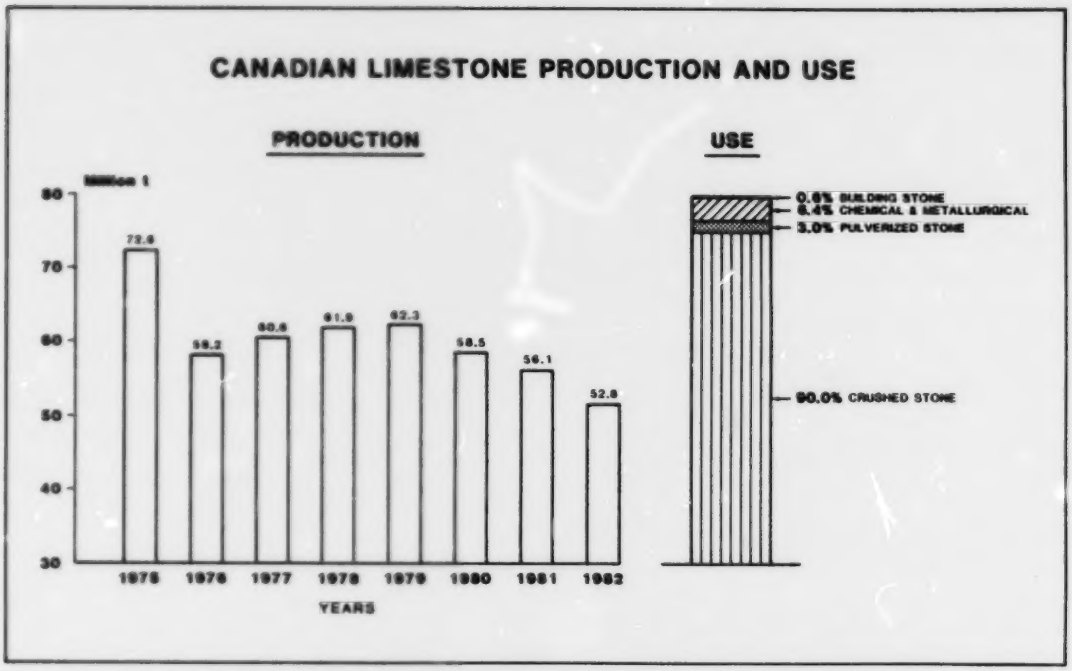
STEEP ROCK RESOURCES INCORPORATED

Plant Location

Perth, Ontario

* Joliette plant now owned by Jolichaux Inc.

Limestone: Large tonnages of low power consumption products



Source: Statistics Canada; Energy, Mines and Resources, Canada.

Comminution power requirement :

crushed product	-	1.5 kWh/t.
ground product*	-	8.5 kWh/t.
ground product -20 µm	-	68 kWh/t.

Estimated comminution power requirement by the limestone industry in 1981 :

crushed product	-	84,000,000 kWh.
ground product	-	14,000,000 kWh.
Total	-	98,000,000 kWh.

* Assuming that the majority of the ground product is for agricultural use.

Background

Limestone is second only to sand and gravel in terms of tonnages produced annually in North America.

About 90% of limestone is sold as crushed stone for such uses as road construction and aggregate for concrete and asphalt. Chemical and metallurgical uses account for 6-7% of shipments. Limestone for these applications is usually required to be high calcium and impurities may be subject to precise specifications. A smaller quantity, about 3% of total limestone production, is marketed in pulverized form for agricultural and filler purposes.

The Production Process

The quarrying and preparation of limestone depends on its intended application.

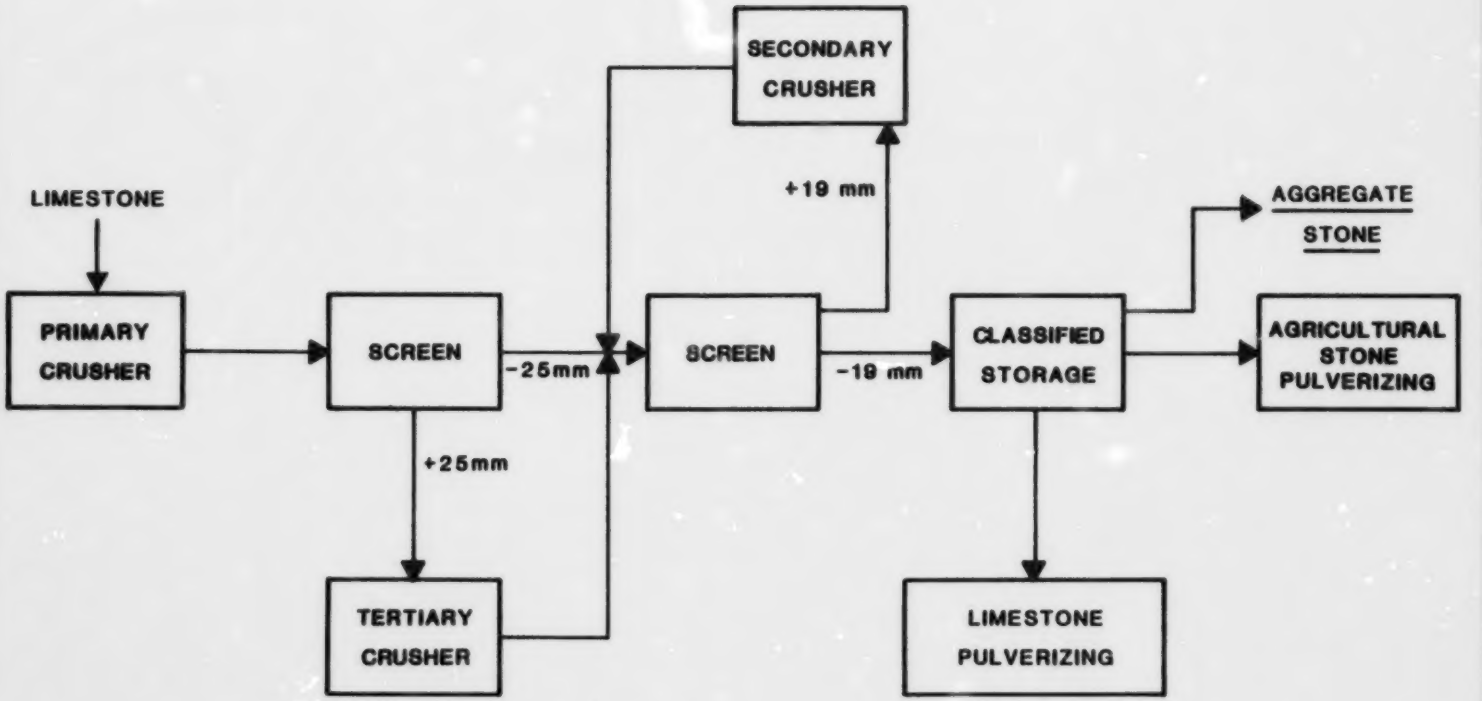
For dimension stone, large, uniform blocks are required. It is almost invariably worked from open pits. Channeling machines are used to make primary cuts for block separation. Once a key block is broken loose, horizontal holes can be drilled beneath adjoining blocks. They are then subdivided into mill blocks and hoisted to the surface. These blocks can be sold as is or further finished by cutting, carving, planing and polishing.

The main use of limestone is as aggregate. The rock is removed by blasting. The type of primary crusher employed depends on the hardness and fracturing qualities of the stone, and particularly on the gradation that is desired in the product. For lime kiln feed, fluxstone and coarse aggregate, jaw or gyratory crushers are necessary. For use as cement kiln feed, impact crushers are preferred because they crush more finely.

The flow sheet on page 74 summarizes a typical production process.

LIMESTONE PROCESS FLOW SHEET

DOMTAR JOLIETTE PLANT



The Role of Comminution

Crushing, produces a range of aggregate products and prepares material for pulverizing. The size specification of the product determines the extent to which the material is comminuted.

Pulverizing, for agricultural stone and filler grade products, limestone is subjected to grinding. Agricultural grades are relatively coarse; 50% less than 0.25 mm. Filler grades may be as fine as 99.5% passing a 45 μm sieve and an average particle size of 10 μm.

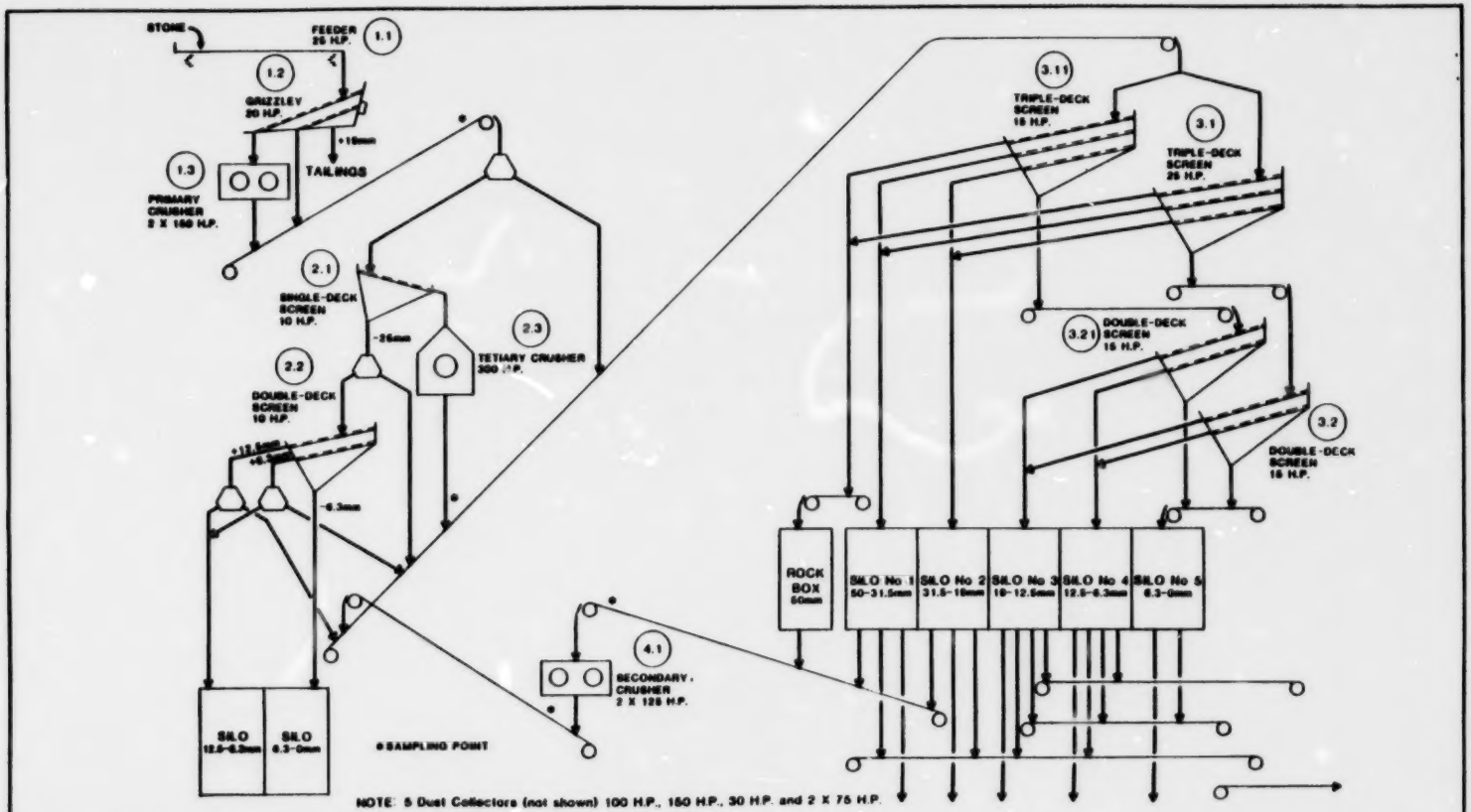
Comminution at the Domtar Plant

The crushing circuit and power levels in kilowatts are given on the diagram on page 76.

The average feed rate to the circuit was estimated at 404 tonnes per hour. The optimum production rate for the mill, if continuously fed, is 680 tonnes per hour.

Grindability. The Hardgrove Index was found to be 66, giving a calculated Bond Index of 9.61 kWh/ton. The tested Bond Index was 8.41 kWh/ton.

The **size distribution** of the primary crusher feed was minus 900 mm, plus 150 mm and mainly minus 450 mm, plus 150 mm.



NOTE: 5 Dust Collectors (not shown) 100 H.P., 150 H.P., 30 H.P. and 2 X 75 H.P.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
1.1	FEEDER	2
1.2	GRIZZLEY	8
1.3	PRIMARY CRUSHER	74
		98
1.4	DUST COLLECTOR	48
2.1	SINGLE-DECK SCREEN	5
2.3	TERTIARY CRUSHER	195
2.4	DUST COLLECTOR	51

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
3.1	TRIPLE-DECK SCREEN	8
3.11	TRIPLE-DECK SCREEN	5
3.2	DOUBLE-DECK SCREEN	6
3.21	DOUBLE-DECK SCREEN	5
3.3	DUST COLLECTOR (SCREEN)	51
3.4	DUST COLLECTOR (CONVYR)	16
4.1	SECONDARY CRUSHER	54
		33
4.2	DUST COLLECTOR	28

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 20/09/84
CHECKED DCS DATE 20/09/84

AGGREGATE CRUSHING & SCREENING
FLOW DIAGRAM

PLANT OF PRODUITS CHIMIQUES DOMTAR - JOLIETTE, P.Q.

PROJECT No. 20010

A typical product size distribution for the crushing circuit is given in the table below.

CRUSHING CIRCUIT TYPICAL PRODUCT SIZE DISTRIBUTION	
mm	% Passing
50.0	100
31.5	98.2
19.0	96.7
12.5	62.7
6.3	32.4

Pulverizing Circuits

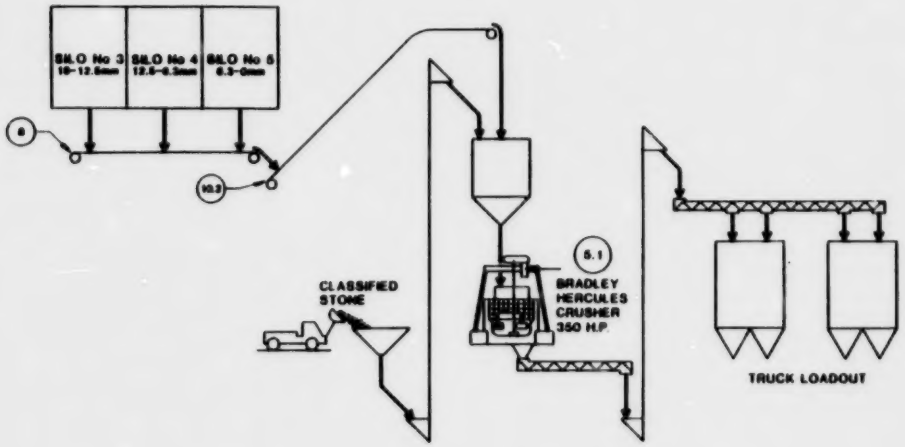
There are two pulverizing processes, one for the relatively coarse agricultural stone, the other for filler products.

The agricultural stone circuit and the power data for the equipment are given in the sketch on page 78. The Bradley Hercules pulverizer was not operating during the study.

The **flowrate** to the mill is 41 t/h, and is normally very steady.

The **size distribution** of feed and product are summarized in the following table.

SIZE DISTRIBUTION % Passing		
mm	FEED Bradley Pulverizer	PRODUCT Agricultural Stone
6.7	100	---
4.75	86	---
3.35	72	100
2.36	58	99
1.18	40	94
0.600	29	80
0.300	24	52
0.150	16	41
0.075	12	---



NOTE: Dust Collector (not shown) 25 H.P.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
5.1	BRADLEY 6000 HERCULES	260
5.2	DUST COLLECTOR	9

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN PGM DATE 82/10/83	LIMESTONE PULVERIZING (SOLPIER) FLOW DIAGRAM	PLANT OF PRODUITS CHIMIQUES DOMTAR - JOLIETTE, P.Q
CHECKED DCS DATE 29/09/84		PROJECT No: 20010

The filler product circuit and power observations are shown in the sketch on page 80.

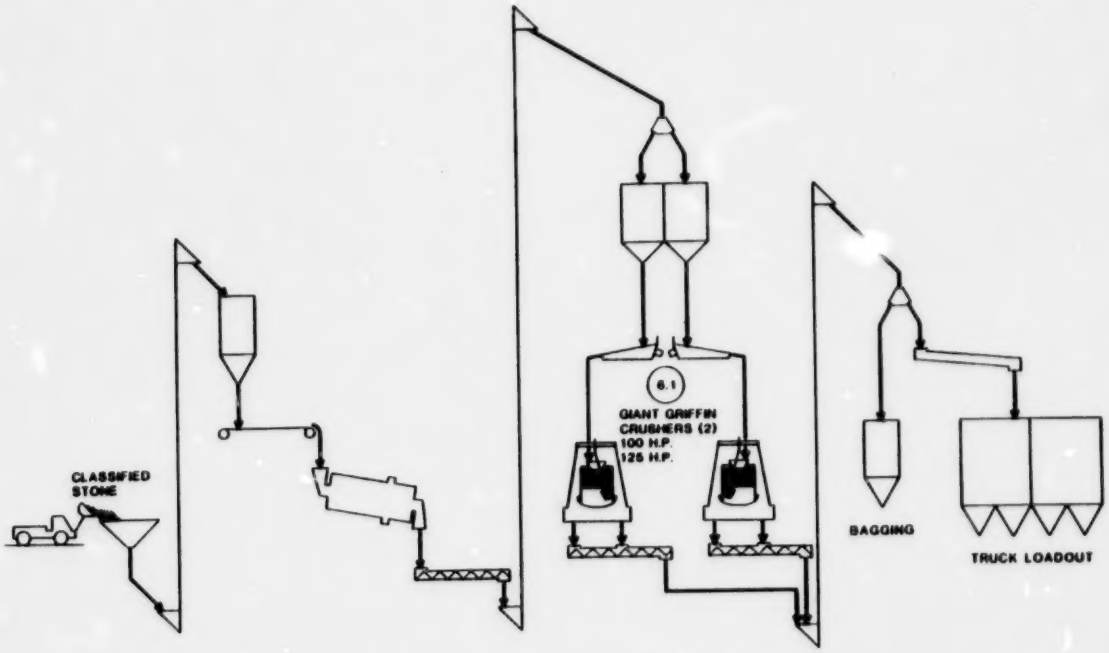
Feedrate to each Griffin Mill was 4.5 t/h.

Particle size distribution of the feed is the same as that for the Bradley Hercules pulverizer.

The product particle size distribution is considerably finer than that of the agricultural stone. The table below summarizes the size distribution from a Sedigraph test.

PARTICLE SIZE DISTRIBUTION OF LIMESTONE FILLER PRODUCT

µm	%
100	85.5
70	72.0
50	61.5
40	55.5
30	49.0
25	45.5
20	41.5
15	35.5
10	27.5
8	23.5
6	18.0
4	13.0
2	6.5



NOTE Dust Collector (not shown) 40 H.P.

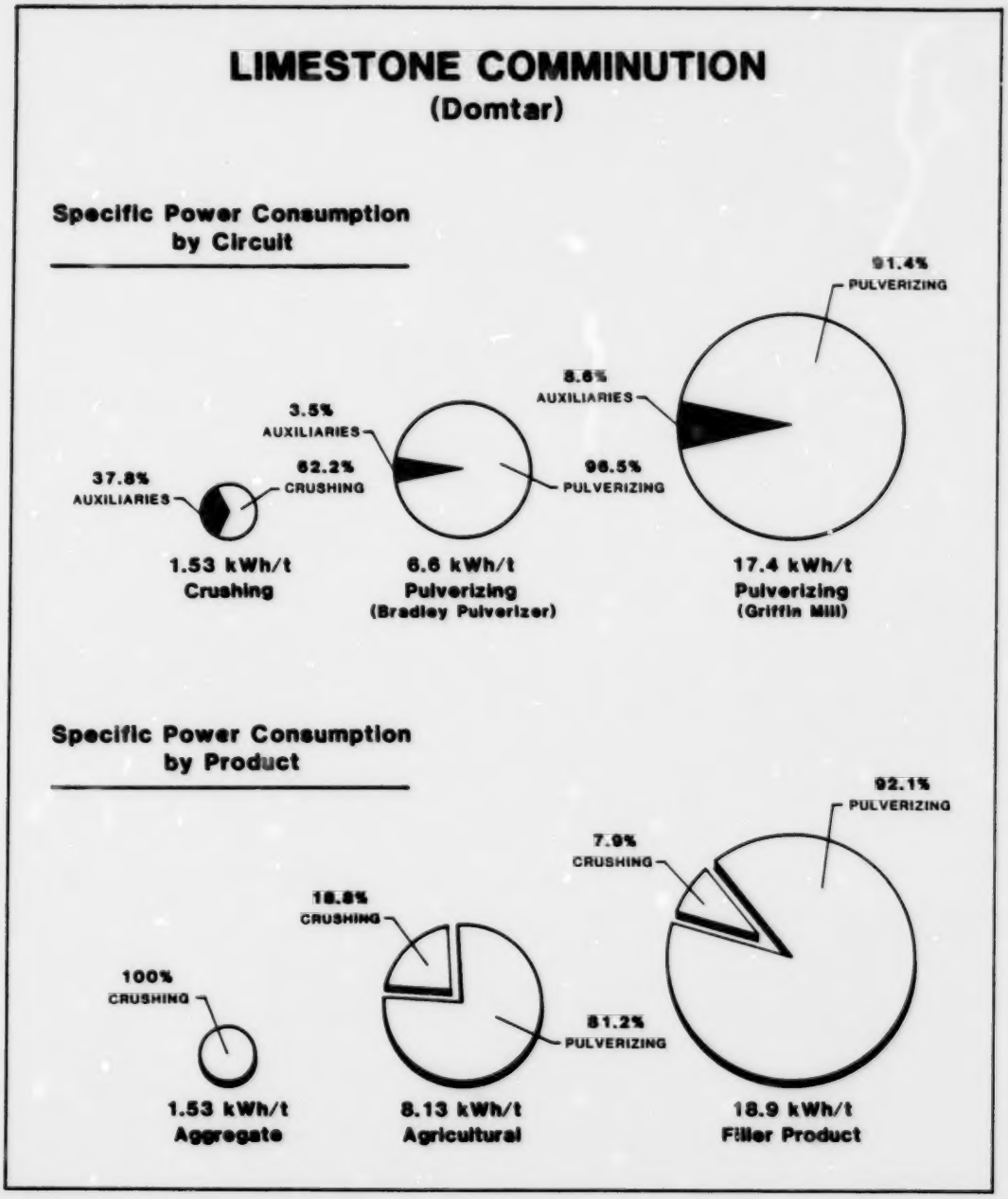
POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
6-1	Giant Griffin - 40" (x2)	72
6-2	Dust Collector	14

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGM DATE 28/09/83	LIMESTONE PULVERIZING (STALCO) FLOW DIAGRAM	PLANT: PRODUITS CHIMIQUES DOMTAR - JOLIETTE, P.Q.
CHECKED DCS DATE 29/09/84		PROJECT No: 20010

Results

The results of the specific power consumption by circuit and the cumulative comminution power consumption by product is given in the diagram below.



Comminution at the Steep Rock Resources Plant

The company operates a quarry at Tatlock, Ontario and a calcite processing plant at Perth. The deposit is unique in its combination of whiteness, high calcium and low magnesium and silica contents.

Three types of products are made:

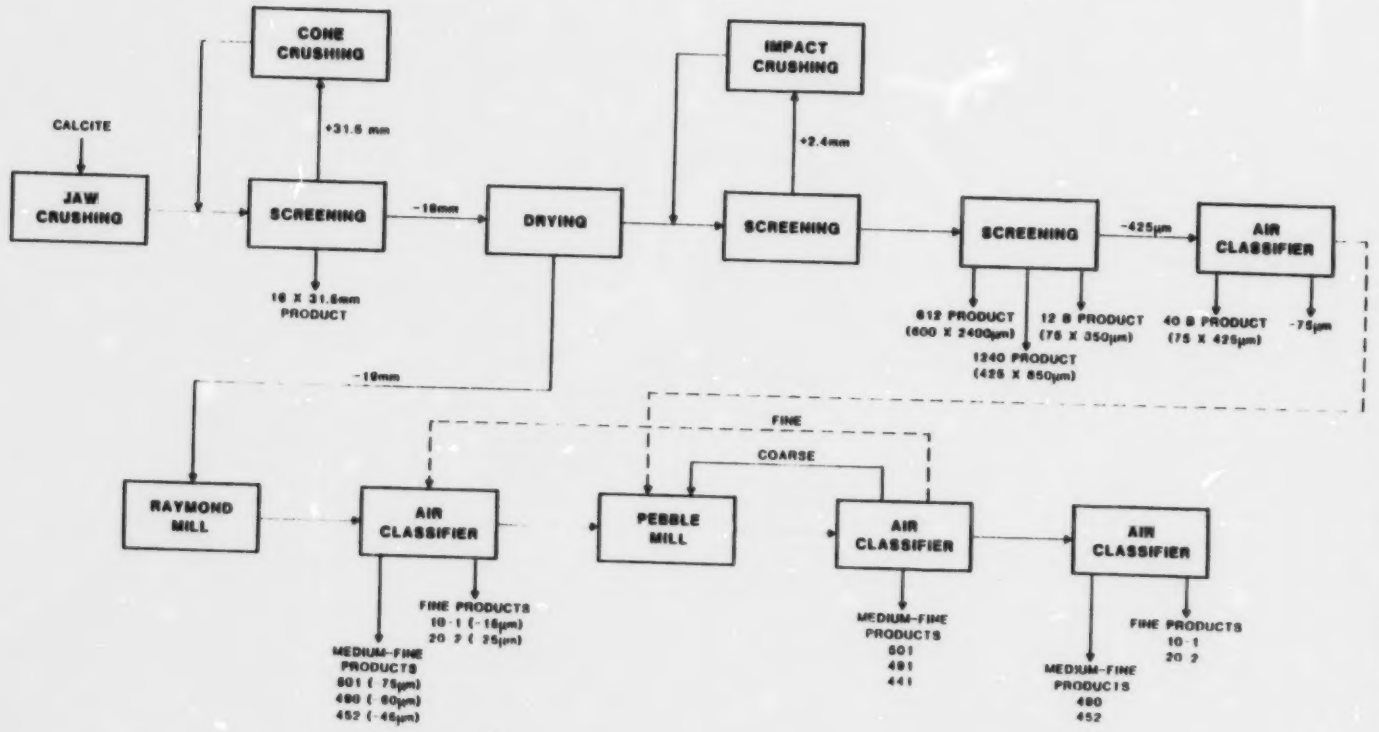
- aggregate stone for white block manufacturing, decorative chips, driveway stone, etc.,
- screened sand grade products for floor tile, stucco mix, cultured marble and animal feed,
- fine and medium-fine ground products for use as fillers in paints, plastics, adhesives and other industrial products.

Process Description

Primary and secondary crushing is done at the quarry where the larger aggregate sizes are screened out and sold. The minus 19 mm product is trucked approximately 40 km to the plant where drying, screening, grinding, and classifying operations are carried out, as shown in the flow sheet overleaf.

CALCITE PROCESS FLOW SHEET

STEEP ROCK CALCITE PERTH, ONTARIO



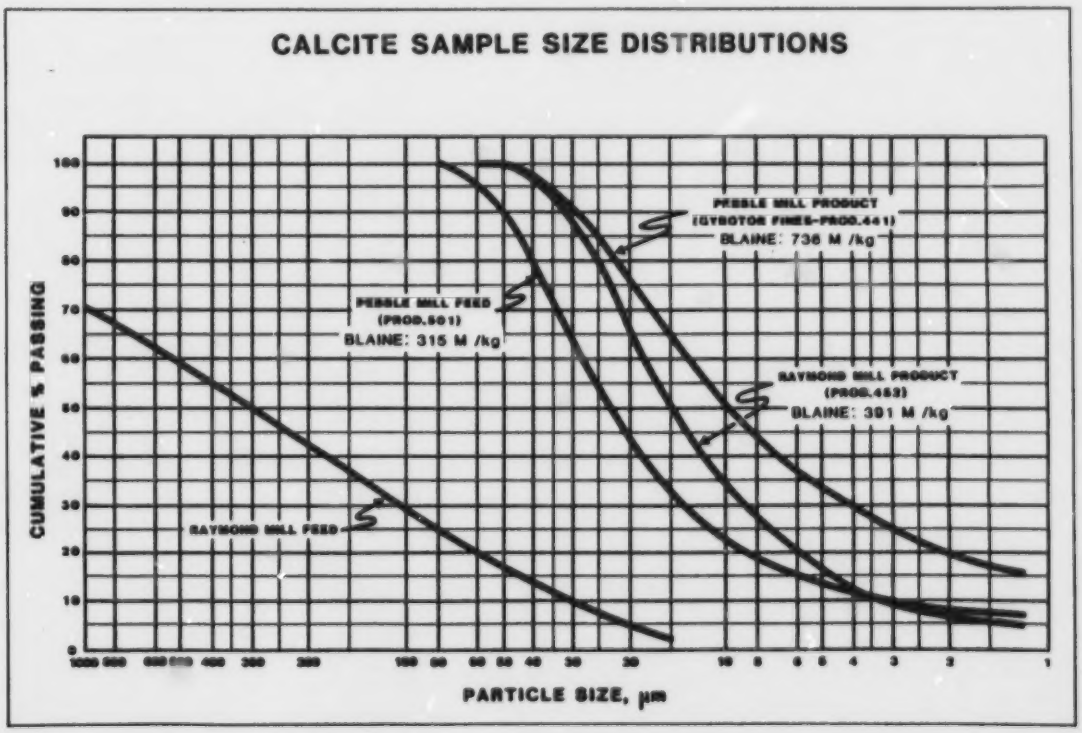
Comminution Processes

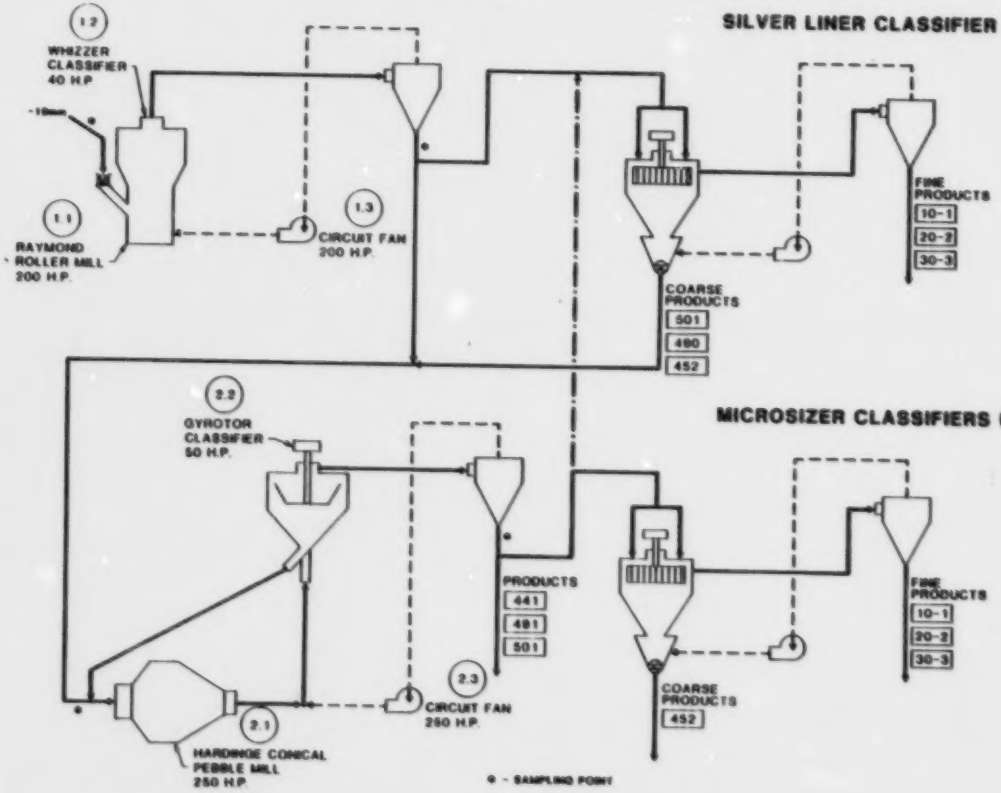
The two grinding circuits, outlined in the sketch on page 85, produce the fine and medium-fine products. The Raymond mil is used for the medium-fine products designated 501, 490, and 452. It is standard operating practice to feed the Hardinge pebble mill with the 501 material in processing the fine grind products.

Flowrates for the mill circuits were estimated to be:

- Raymond mill (452 Product) 5.4 t/h
- Pebble mill (441 Product) 5.0 t/h

Particle size of the feed to the mill circuits is summarized on the chart which gives both size distribution and Blaine specific surface area data.





POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
1-1	Raymond Roller Mill - 6669	140
1-2	Whizzer Classifier	14
1-3	Circuit Fan	76
2-1	Hardinge Conical Pebble Mill - 10' x 84"	112
2-2	Gyrotor Classifier	15
2-3	Circuit Fan	112

CANADA CEMENT LAFARGE LTD.
MONTREAL

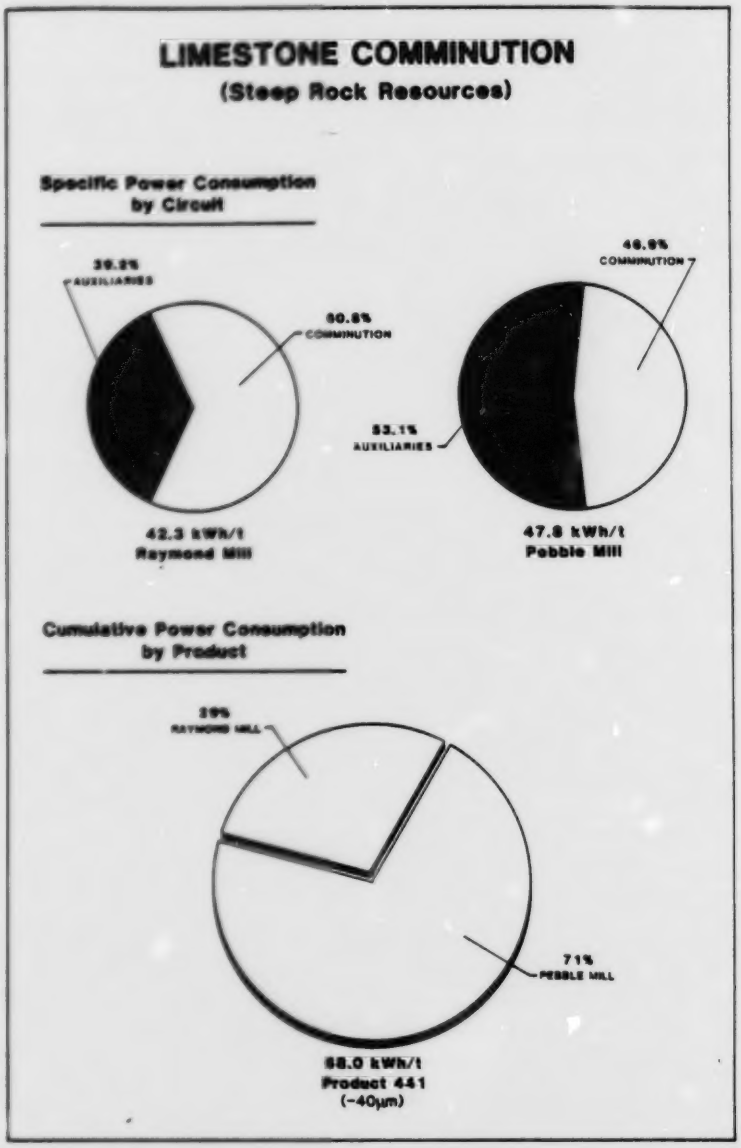
DRAWN QFJ DATE 30-08-84
CHECKED DCS DATE 20/09/84

CALCITE GRINDING
RAYMOND AND PEBBLE MILL CIRCUITS
FLOW DIAGRAM

PLANT N° ____

PROJECT No. 20010

The power consumption results for the circuits which are shown in the pie diagrams indicate that the mills have relatively similar specific consumptions.



The reported data does not include consumption for crushing and drying. Experience has shown this consumption to have minimal effect on product energy.

Conclusions

Most of the product volume in the industry is low energy crushed stone.

The Steep Rock plant has very up-to-date technology, especially in the area of classification.

Recommendation

The efficiency of the industry and low overall power consumption suggests that this is not a high priority mineral for further study.

MICA

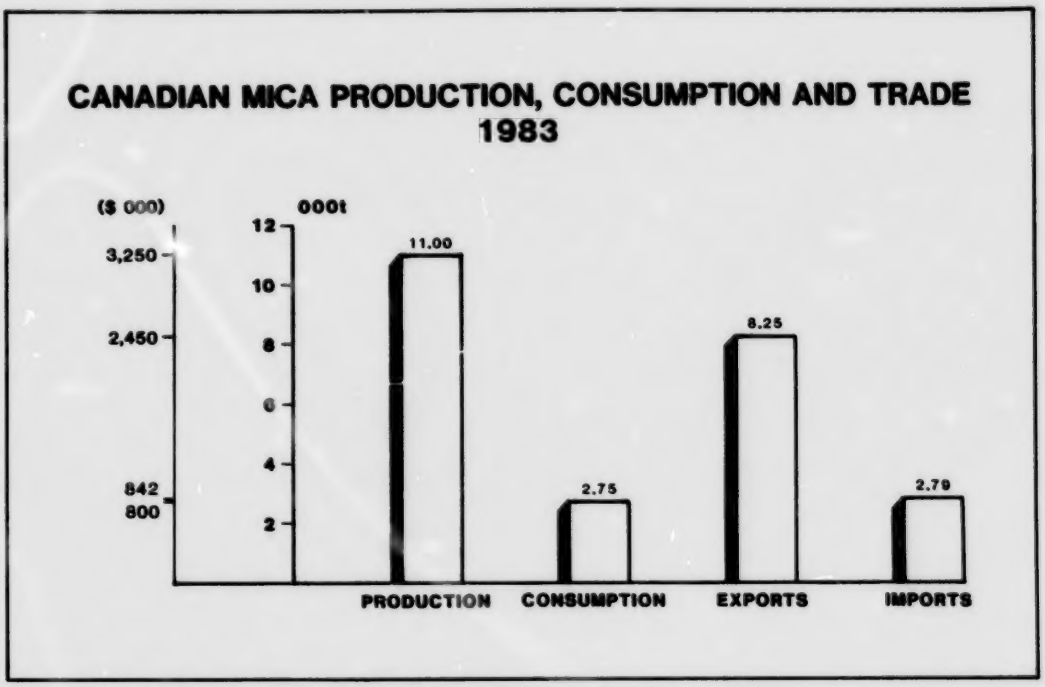
Participating Company

MARIETTA RESOURCES INTERNATIONAL, LTD.

Plant Location

Boucherville, Quebec

Mica: High specific power consumption - low production volume



Source: Canadian Mining Journal, February 1984.
Statistics Canada, Energy, Mines and Resources, Canada.

Specific comminution power consumption by product :

coarse - 85 kWh/t.
fine - 573 kWh/t.

Estimated industry power consumption in comminution for 1983 : 2,950,000 kWh.

Background

The only company producing mica in Canada is Marietta Resources International Ltd. (MRI) with the participation of Société Minéralurgique Laviolette Inc. The company mines phlogopite mica at the Bédard mine near Parent, Quebec.

Marietta Resources International Ltd. (MRI) has been in operation commercially since 1976 and is currently at a production level of between 10,000 and 12,000 tonnes annually.

The Bédard deposit is estimated to be 30 million tons of 85-95 percent pure ore.

Mining is done by open pit with a recovery rate of seventy-five percent.

Koisumi Group Canada Ltd. has indicated interest in developing a source of muscovite mica near Kaladar, Ontario. Some materials have been sent to Japan to develop processing techniques for a material suitable for the plastic industry.

The United States is the major producer with 63% of world output. Canada is fourth with 4%.

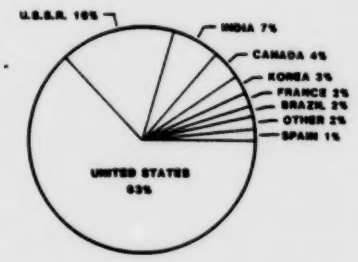
MAJOR WORLD MICA PRODUCERS

ALL FORMS (Ground, Flake & Sheet)
(tonnes)

COUNTRY	1981 (prelim.)	1982 (est.)
UNITED STATES	226,800	183,250
U.S.S.R.	47,170	48,080
INDIA	40,220	21,550
CANADA	11,122	10,079
REPUBLIC OF KOREA	10,000	9,980
FRANCE	6,800	6,490
SPAIN	5,000	3,300
BRAZIL	4,500	4,500
OTHER	10,120	6,160
TOTAL	361,742	293,399

SOURCE: U.S. Bureau of Mines

BREAKDOWN OF WORLD PRODUCTION BY COUNTRY (1982 est.)



Products and Uses

MRI classifies its suzorite mica as coarse (Z), fine beneficiated (S) and ultra fine (FE). They market about 20 different blends, based on purity, degree of fineness and aspect ratio *.

Typical uses are in;

- thermoplastics, thermosets, and glass and phosphate bonded mica (to reinforce and stiffen),

- tape joint compound, cement board and pipe, asphaltic coatings, brake lining and thermal insulation (to replace asbestos),

- oil well drilling muds, radiation sealants, coatings, lining and plastics (to reduce permeability),

- rubber mold release, fire extinguishers, and asphalt roofing (to lubricate, prevent caulking and sticking).

* Average diameter of a flake divided by its thickness.

The major physical and chemical properties of suzorite mica are:

PHYSICAL PROPERTIES	
Color	: Amber brown
Shape	: Thin flakes
Particle Nominal Diameter	: 20 microns to 0.64cm (0.25 in), depending on grade.
Particle Thickness	: 0.5 to 300 microns, depending on grade.
Bulk Density (Scott Volumeter)	: 145-640kg/m^3 (9-40 pcf), depending on grade
Specific Gravity	: 2.9
Hardness - Moh's	: 2.5 - 3.0
Ph (of aqueous suspension)	: 7.5
Water Solubility	: Virtually insoluble

CHEMICAL COMPOSITION	
COMPONENTS	% BY WEIGHT
SiO_2	40.7
Al_2O_3	15.8
MgO	20.6
K_2O	10.0
Total Fe (as FeO)	8.9
F	2.2
H_2O+	3.0
BaO	0.5
Na_2O	0.5
TiO_2	0.4
Cr_2O_3	0.2
NiO	0.3
V_2O_5	Less 0.1
S and P	Less 0.1

The Production Process

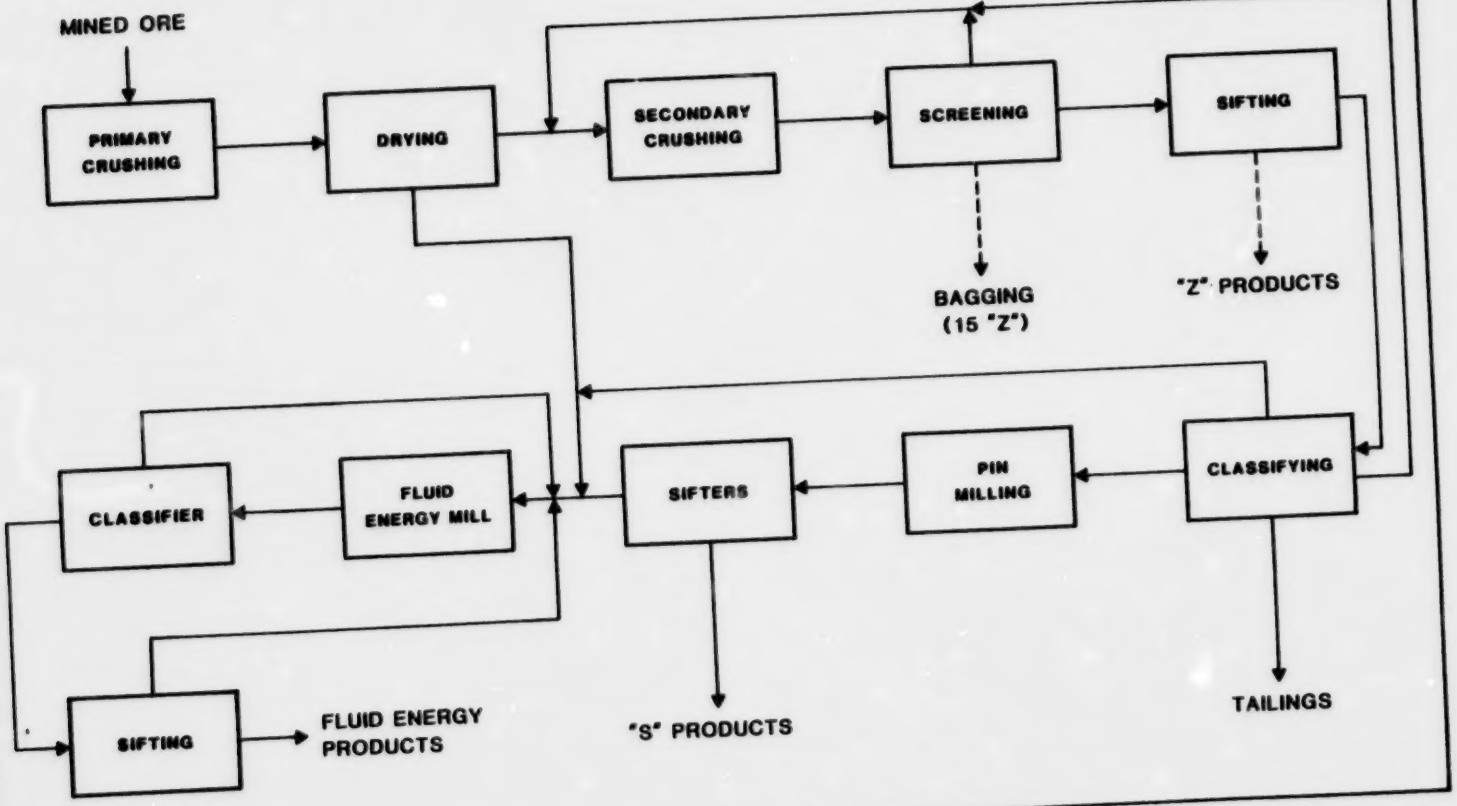
An overview of the production process is shown on the flow sheet overleaf.

There are three distinct phases, each defined by its product; Z, S and FE.

Comminution in the true sense is a limited operation except in the primary crushing stage, which receives the mixed ore from the stockpile. Elsewhere, the impact crushers, pin mill and fluid energy mill are used to delaminate the flakes.

MICA PROCESS FLOW SHEET

MARIETTA RESOURCES LTD., BOUCHERVILLE, QUEBEC



The Role of Comminution

There are three comminution steps in mica production:

Crushing, where the mined ore is reduced to a suitable size for the pin mill feed or for bagging as "Z" products.

Pin Milling, where material is further reduced in size to give a ground product ("S") or feed for the fluid energy mill.

Fluid Energy Milling, where raw mica and dust are further processed to produce products, 40-95% passing 45 um.

Comminution at the Boucherville plant

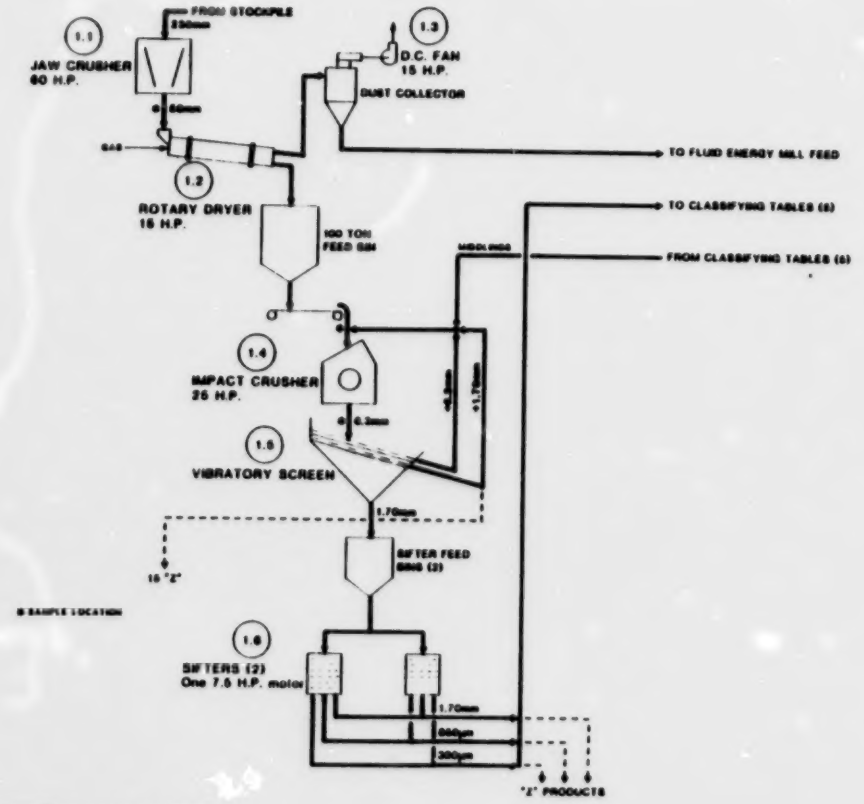
Crushing

The crushing circuit is shown schematically on page 94. Power levels are summarized on the flow diagram.

The **flowrate** averages 6 tonnes per hour of dry ore, but fluctuates depending on ore moisture content.

As shown, there are two crushing stages reducing the initial 230 mm feed to 50 mm then to 6.3 mm.

There is a limited production of coarse gangue contaminated material. But, primarily the material from the crushers is the feed for the "Z" product sifters.



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
1.1	Jaw Crusher	7.0
1.2	Rotary Dryer	3.7
1.3	Dryer D.C. Fan	9.0
1.4	Impact Crusher	6.7
1.5	Vibratory Screen (Air Operated)	-
1.6	"2" Product Sifters	1.3

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN QFJ DATE 20/01/84
CHECKED DCS DATE 20/09/84

CRUSHING CIRCUIT

PLANT of MARMETTA RESOURCES LTD
ROUCHEMONT, QUEBEC

PROJECT No: 20010

Milling

The "Z" product feed is classified and only the fine fraction becomes feed for the pin mill, as shown on the circuit flow diagram.

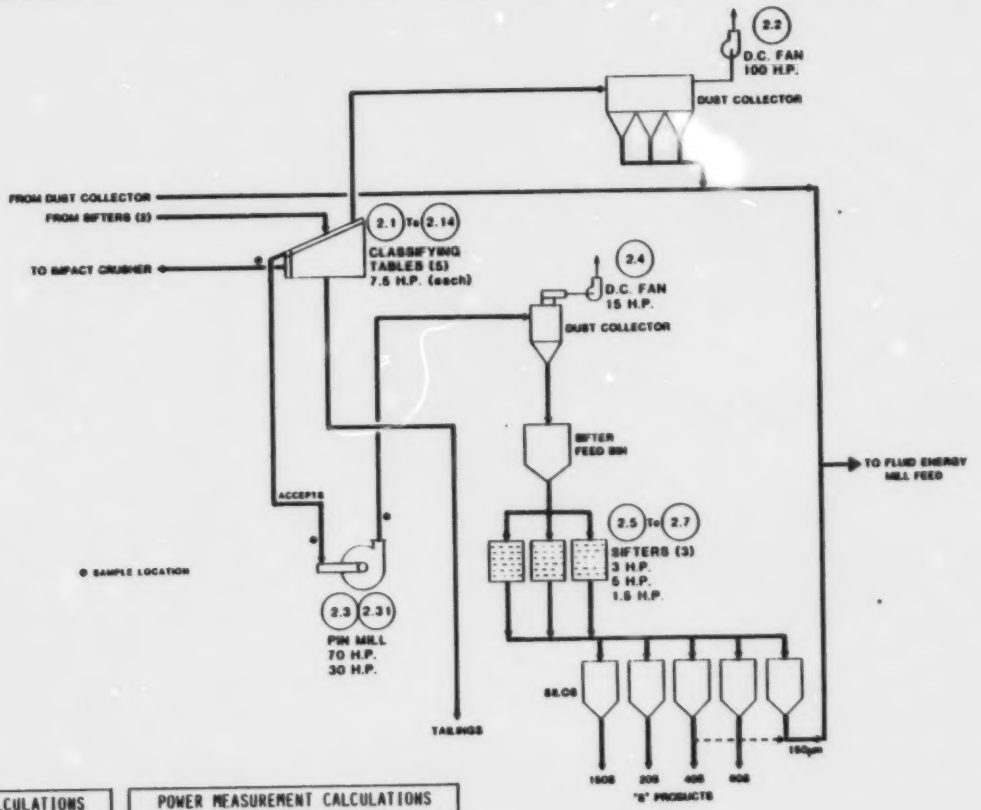
Flowrate to the circuit obtained from plant records was 1.32 t/h. The pin mill product flows through a dust collector prior to entering the sifters which produce "S" products and feed for the fluid energy mill circuit.

Particle size distributions of the feed and typical product are shown in the table below.

SUZORITE MICA SIZE DISTRIBUTION % Passing		
Size	15 "Z" PRODUCT	20 "S" PRODUCT
6.3 mm	100	
4.75	84.1	
2.36	23.5	100
1.18	1.7	33.3
600 µm	0.7	2.4
300	0.5	1.6
150	0.3	1.0

The **grindability** of mica was determined by the Hardgrove method. The Bond index, which could not be determined experimentally because of the flaky nature of the material, was calculated from the Hardgrove results.

PRODUCT	GRINDABILITY	
	HARDGROVE	BOND INDEX
15 "Z"	16	35 kWh/T
20 "S"	13	42 kWh/T



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
2-3	Pin Mill (Opposite Direction)	26.0
2-31	Pin Mill (Opposite Direction)	6.3
2-40	Pin Mill D.C. Fan	7.2
2-50	Sifters #5	1.8
2-60	Sifters #6	1.8
2-70	Sifters - 150S	---

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
2-1	Classifying Table #1	3.6
2-11	Classifying Table #2	3.6
2-12	Classifying Table #3	3.7
2-13	Classifying Table #4	2.4
2-14	Classifying Table #5	3.5
2-2	Classifying Tables D.C. Fans	45.2
2-3	Pin Mill (Same Direction)	16.9
2-31	Pin Mill (Same Direction)	3.4

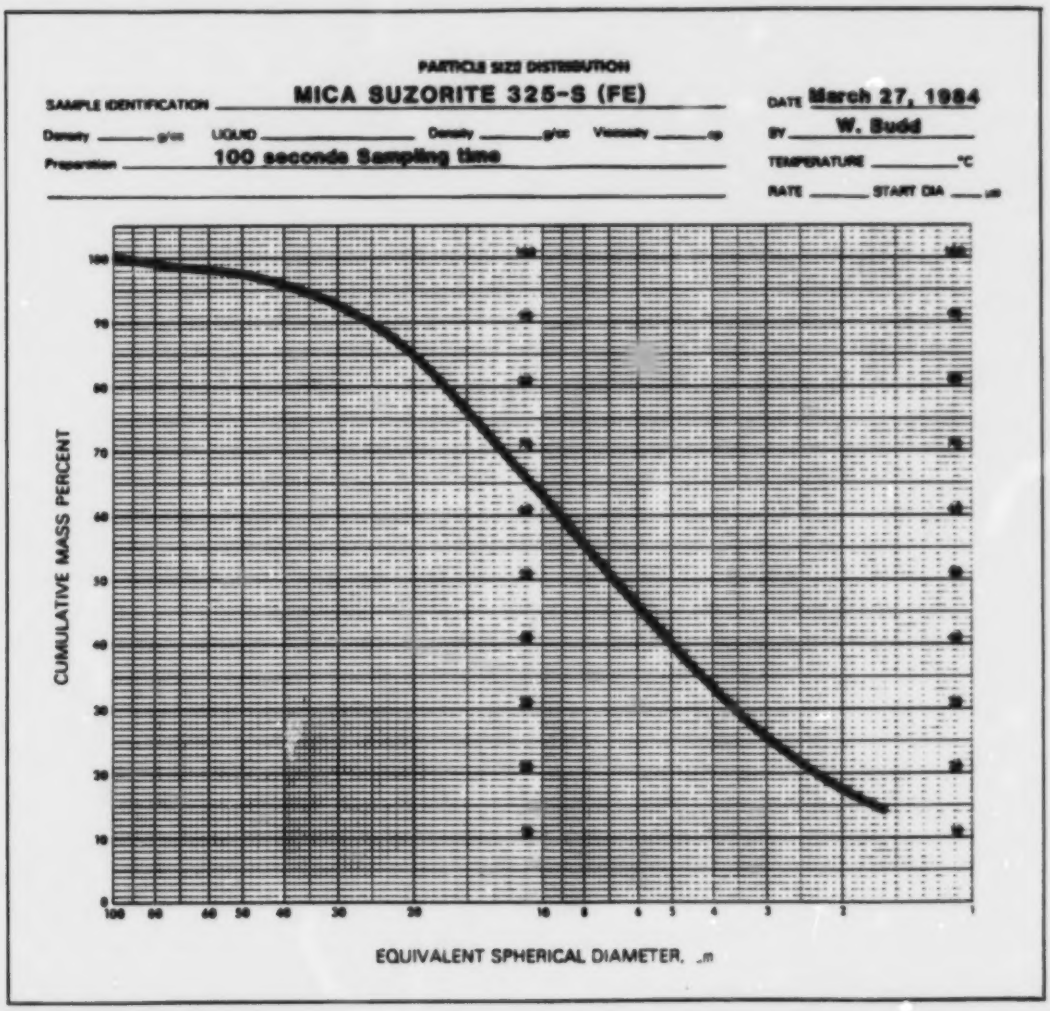
CANADA CEMENT LAFARGE LTD.
MONTREAL

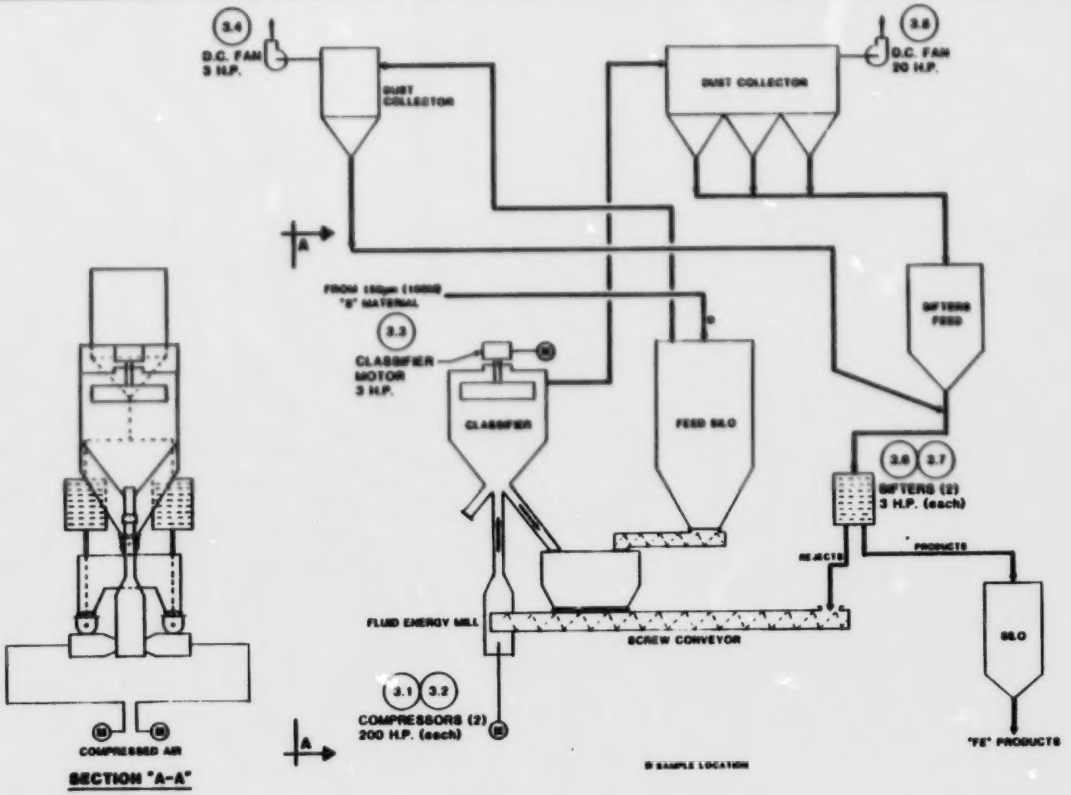
DRAWN GFJ DATE 20/01/84	PIN MILLING CIRCUIT	PLANT OF MARIETTA RESOURCES LTD. BOUCHERVILLE, QUEBEC
CHECKED DCG DATE 20/09/84		PROJECT No. 20010

The Fluid Energy Mill is used for ultra fine products: 40 to 95 percent passing 45 μm. A schematic of the circuit is on page 98.

Flowrate to the mill, as determined from plant records, was 0.68 t/h.

Particle size distribution. As previously mentioned, the "S" product, whose size distribution is given in the table on page 95, is feed for the FE mill. The size distribution of the product is shown in the Sedigraph trace below.


PARTICLE SIZE DISTRIBUTION
SAMPLE IDENTIFICATION MICA SUZORITE 325-S (FE)
DATE March 27, 1984
BY W. Budd
Preparation 100 seconds Sampling time
CUMULATIVE MASS PERCENT
EQUIVALENT SPHERICAL DIAMETER, μm



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
3.1	FLUID ENERGY MILL COMPRESSOR #1	147.5
3.2	FLUID ENERGY MILL COMPRESSOR #2	172.8
3.3	CLASSIFIER MOTOR	1.5
3.4	FLUID ENERGY MILL SMALL D.C. FAN	3.2
3.5	FLUID ENERGY MILL LARGE D.C. FAN	6.0
3.6	FLUID ENERGY SIFTER #9	0.7
3.7	FLUID ENERGY SIFTER #10	0.8

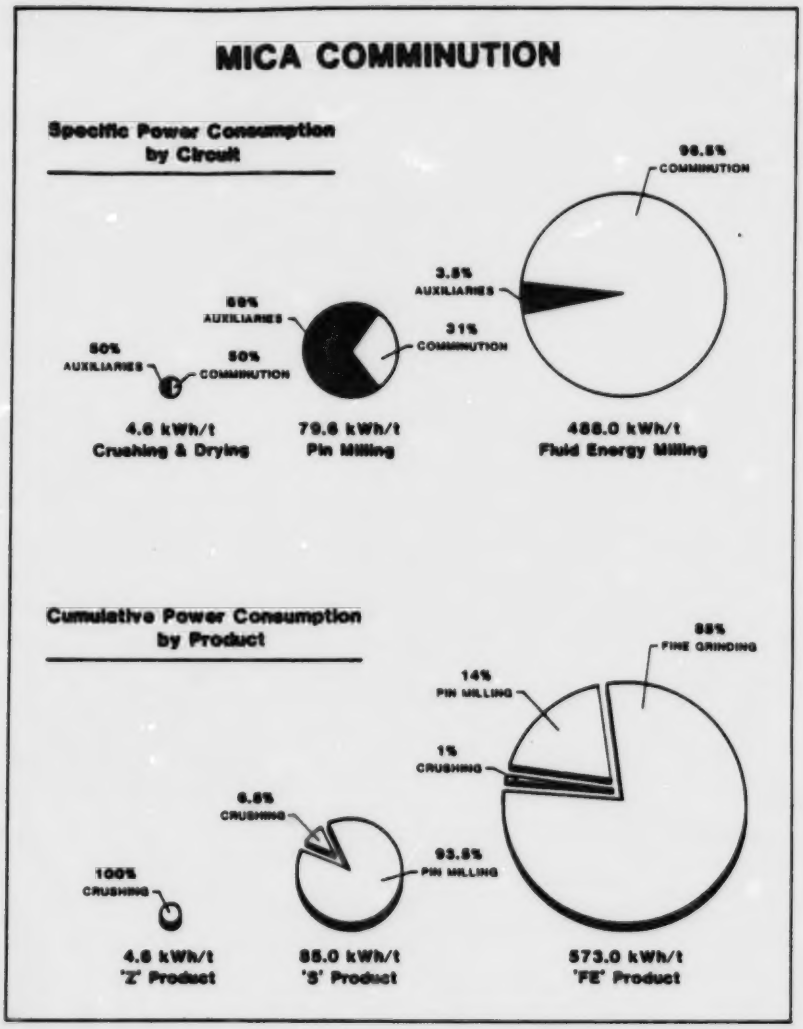
PLANT AIR SUPPLY		
No.	EQUIPMENT	kW AVG.
1	PLANT/D.C. AIR COMP.	40.2
1	PLANT/D.C. AIR COMP.	42.5

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN GFJ DATE 20/01/84	FLUID ENERGY MILL CIRCUIT	PLANT OF MARMETTA RESOURCES LTD SOUCHERVILLE, QUEBEC
CHECKED DCB DATE 20/09/84		PROJECT No: 20010

Results

The specific power consumption in the crushing and milling circuits are summarized below.



The high specific power consumption is related both to the low Hardgrove index, which indicates that it is the most difficult to grind of the ten minerals studied, and the fineness of the "FE" product. Reported product consumptions also include an additional 62.2 kWh/t for supplying compressed air to dust collectors, etc., determined from electrical measurements and an estimated average plant production rate.

Conclusions

Conclusions of the study were found to be:

- the production of fine products, below 95 µm, is very energy intensive;
- the plant air and dust control systems are significant power consumers;
- energy savings may be achieved by using other types of milling equipment;
- better classification of fine product could possibly achieve increased production;
- that mica is extremely abrasive, requiring specialized materials and methods of milling.

Recommendations

Recommendations to the industry to achieve energy savings are:

- investigate other types of mills for delamination and fine grinding;
- test other types of materials for their abrasiveness towards mica;
- test other types of classifying equipment to reduce the recirculation load;
- due to the low bulk density of the beneficiated mica, have fine grinding units located near market centers.

NEPHELINE SYENITE

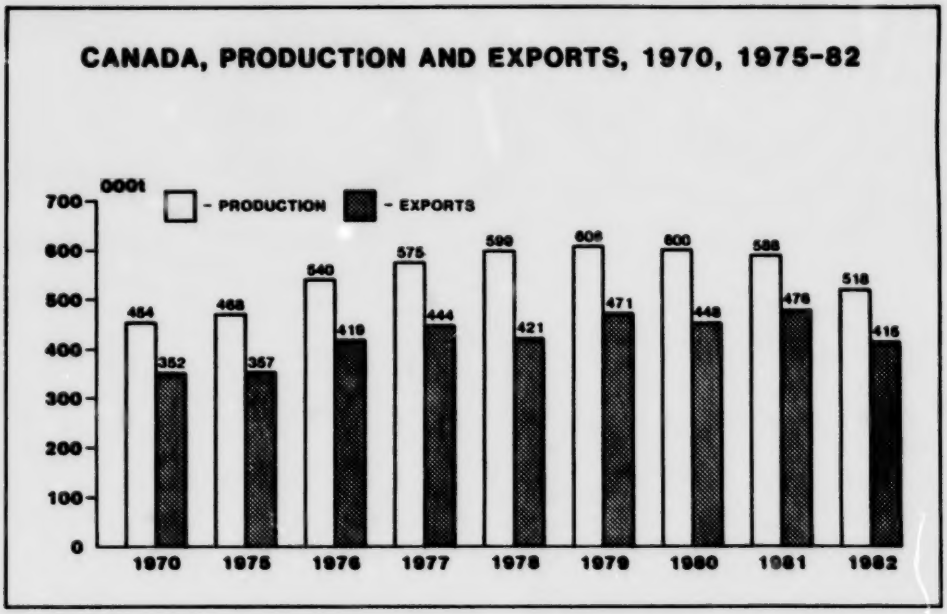
Participating Company

INTERNATIONAL MINERALS AND CHEMICAL CORPORATION

Plant Location

Blue Mountain, Ontario

Nepheline Syenite: High specific energy consumption for fine products, small volume



Source: Canadian Minerals Yearbook 1982, EMR Canada.

Average comminution power requirement : *34.5 kWh/t.

Estimated average annual comminution power requirement by the nepheline syenite industry : 20,000,000 kWh.

Background

Canadian nepheline syenite products are manufactured by two companies operating quarries and mills in Ontario.

Canada exports about three-quarters of its production with 85% of exports going to the United States.

* 70% glass grades, 16% ceramic grades, 14% fillers.

Products and Uses

NEPHELINE SYENITE PRODUCTS AND USES (INC Product Range)		
"A" GRADE PRODUCTS (Fe_2O_3 = 0.08%)	PARTICLE SIZE	USAGE
1. Apex 700	90% minus 10 µm 60% minus 5 µm 40% minus 3 µm	fillers
2. Apex 400	90% minus 20 µm 60% minus 10 µm 38% minus 5 µm	
3. Peak	96% minus 45 µm	ceramics
4. Crest	95% minus 45 µm	
5. C-3	92% minus 45 µm	
6. C-4	88% minus 45 µm	
7. Super 40 "A" Grade	100% minus 425 µm	clear glass manufacture
8. 40 Mesh "A" Grade	97% minus 425 µm	
9. 40 Mesh High Fines "A" Grade	95% minus 425 µm 23% minus 75 µm	
10. 30 Mesh "A" Grade Summit "F"	100% minus 600 µm	
11. 30 Mesh "A" Grade Summit "W"	100% minus 600 µm	
"B" GRADE PRODUCTS (Fe_2O_3 = 0.30%)		glass containers
1. Super 40 Mesh "B" Grade	100% minus 425 µm	
2. 30 Mesh "B" Grade Ridge	99% minus 600 µm	
3. 30 Mesh High Fines "B" Grade	100% minus 600 µm 31% minus 75 µm	
CRUDE		rockwool
1. Half Plus	100% Minus 50 mm Plus 25 mm	

When used for glassmaking, nepheline syenite has a typical size distribution between 600 and 75 µm, an alumina content in excess of 22%, an alkali content of about 14%, and an iron oxide content of less than 0.08%.

Used as a flux in ceramics, a fineness of less than 75 µm is required, as well as the aforementioned chemical specification.

As filler, the important qualities are particle size of less than 20 µm and high dry brightness.

A typical chemical analysis is as follows.

Component	%
SiO_2	60.1
Al_2O_3	23.3
Fe_2O_3	0.07
CaO	0.7
MgO	0.1
Na_2O	10.1
K_2O	4.9
LOI	0.65

The Production Process

A typical process flow sheet is shown overleaf.

The nepheline syenite process deals mainly with size reduction and control of iron content. Control of alumina and alkalies is by selective mining. Ore received at the plant has been selectively quarried and blended, based on information from drill core evaluation.

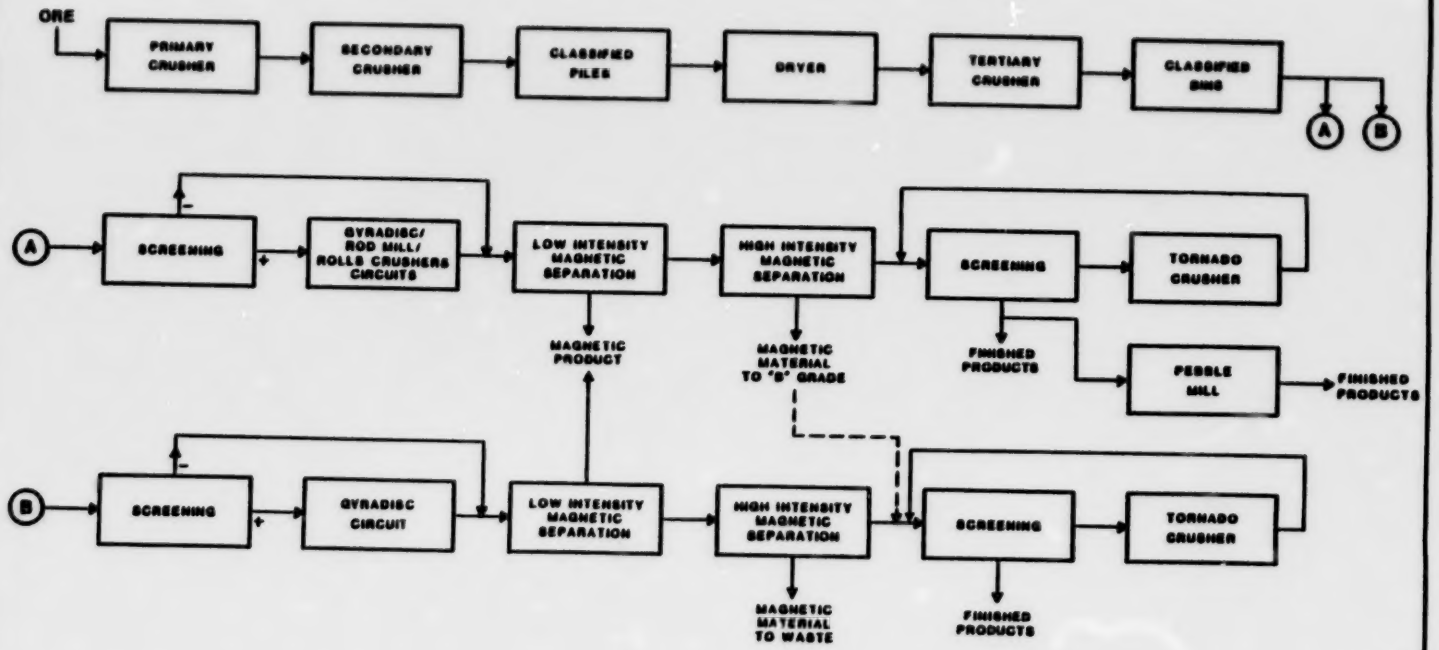
Ore is reduced in jaw and cone crushers before being dried. The dried ore is further reduced in impact or cone crushers. The material is then screened and the oversize further reduced by roll and gyradisc crushers and by rod mill grinding.

Magnetite and iron-bearing minerals are removed, using low and high intensity magnetic separators. Beneficiation also occurs by wasting dust from process dust collectors in the crushing circuits.

Final screening produces various products for the glass industry.

Ceramic and filler products are ground in pebble mills operating in closed circuit with air classifiers.

NEPHELINE SYENITE
SUMMARIZED PROCESS FLOW SHEET
IMC – BLUE MOUNTAIN PLANT, ONTARIO



The Role of Comminution

There are three comminution steps in nepheline syenite processing.

Crushing, where the ore is reduced to a size suitable for feeding to coarse grinding. Drying also takes place at this stage.

Exolon* Feed Preparation, where crushed ore is further reduced to 600 μm as feed for the magnetic separators.

Fine grinding, where beneficiated material is ground to about 95% minus 45 μm. A special air sifter classifier operates in closed circuit with the pebble mill and produces 90% minus 10 and 20 μm products.

Comminution at the Blue Mountain Plant

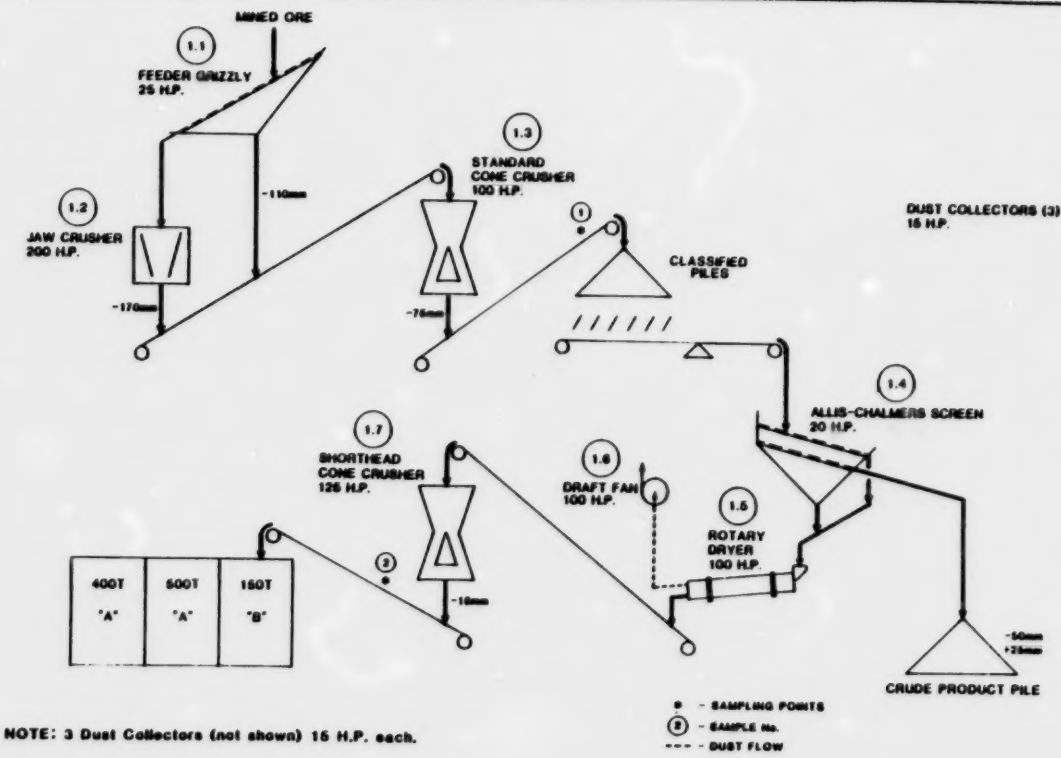
The Crushing Circuit

The circuit is shown schematically on page 106. Rated power (HP) and average demand (kW) in operation are summarized on the sketch.

The circuit is made up of two sections: one involving primary and secondary crushers, the other involving dryer and tertiary crusher. **Flowrate** through primary and secondary crushing was 190 t/h, while drying and tertiary crushing flowrate was 91 t/h.

Primary crusher feed **particle size distribution** was estimated to be -900 +50 mm with most of the material -450 +150 mm. Primary crusher product was estimated to be -175 mm with most of the material -100 +50 mm.

* The trade name of a high-intensity magnetic separator.



NOTE: 3 Dust Collectors (not shown) 15 H.P. each.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
1-1	Feeder Grizzley	-
1-2	Jaw Crusher	56
1-3	4' Standard Cone	28
1-4	Allis-Chalmers Screen	-
1-5	Rotary Dryer	54
1-6	Draft Fan	75
1-7	4-1/4' Shorthead Cone	24
1-8	Jaw Crusher Dust Collector	10
1-9	Cone Crusher Dust Collector	10
1-10	Screen Dust Collector	9

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN GFJ DATE 22/09/83	ORE PREPARATION CIRCUIT FLOW DIAGRAM	PLANT MCORE MC - HAVELOCK, ONTARIO
CHECKED DCS DATE 29/09/84		PROJECT No. 20010

Size distributions for secondary and tertiary crusher products are as follows.

	Product (% Passing)	
Size (mm)	Secondary Crusher	Tertiary Crusher
100	100	-
75	95.7	-
50	87.5	-
31.5	-	100
25	56.8	98.7
19	48.6	94.2
12.5	38.0	81.3
4.75	24.5	50.6
1.18	16.6	33.5
0.3	7.1	20.9

Grindability. The Bond and Hardgrove Indices on the ore were determined to be 13.8 kWh/T and 41, respectively.

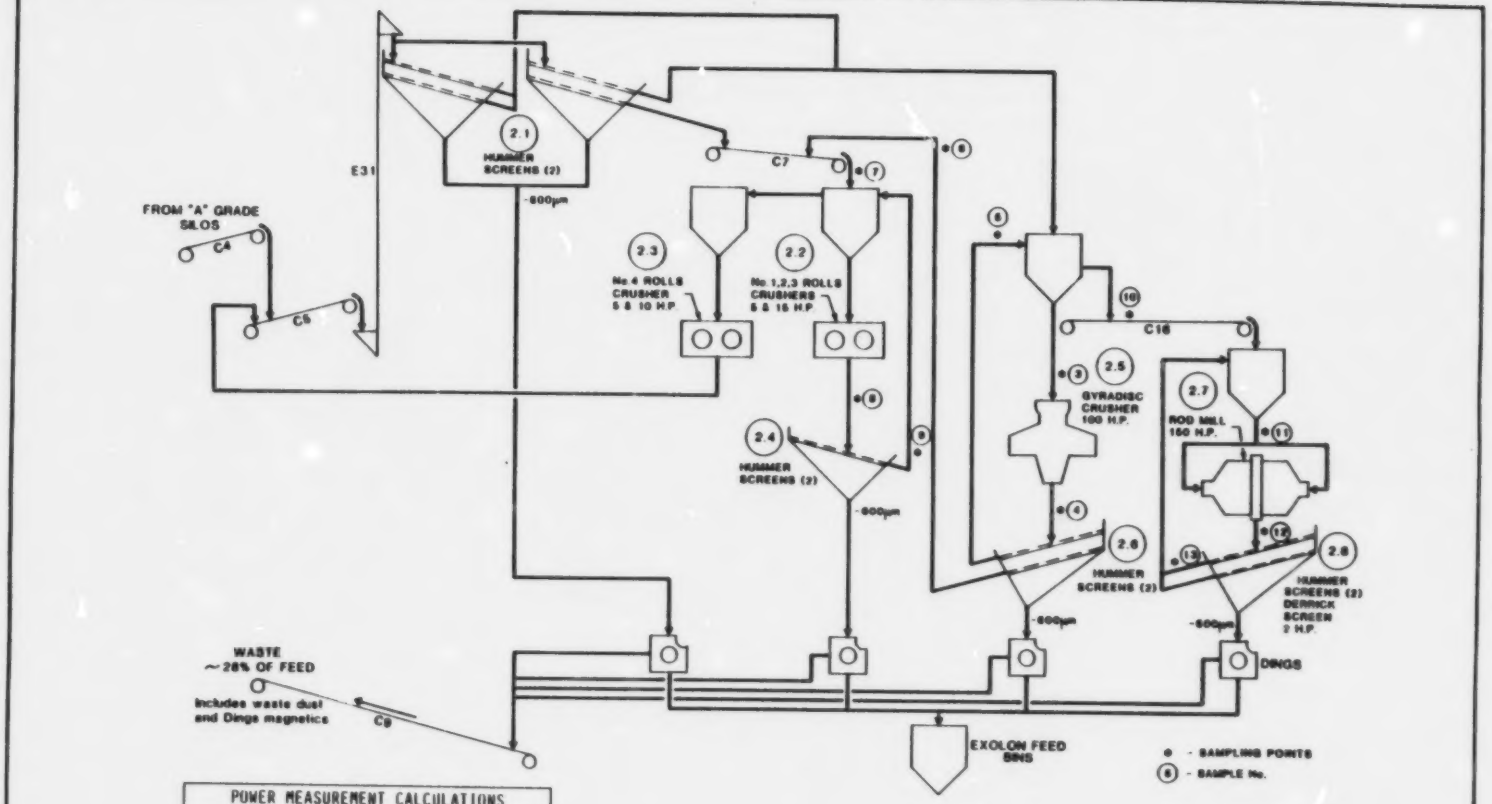
The Exolon Feed Preparation Circuit

The circuit is shown schematically on page 108. Rated power and average demand are summarized on the sketch.

The **flowrate** of beneficiated material from this circuit is 30 t/h.

Particle size distribution of discharge material from each of the comminution machines is characterized as follows.

	Discharge (% Passing)		
Size (mm)	Gyradisc	Rolls	Rod Mill
25	100	-	-
12.5	91	-	-
9.5	78	100	100
2.36	42	87	99
1.18	32	62	91
0.6	18	26	38
0.3	8	10	19
0.15	2	4	10



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
2.1	4'x10' Hummer Screens (2)	1.6
2.2	#1, 2, 3 Rolls Crushers	8.3
		29
2.3	#4 Rolls Crusher	1.7
		5
2.4	4'x10' Hummer Screens (2)	1.6
2.5	36" Gyradisc Crusher	44
2.6	4'x10' Hummer Screens (2)	1.6
2.7	6'x12' Rod Mill	74
2.8	4'x10' Hummer Screens (2)	1.6
	3'x10' Derrick Screen	0.8

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN QFJ DATE 22/09/83
CHECKED DCS DATE 20/09/84

EXOLON FEED PREPARATION FLOW DIAGRAM

PLANT OF BSCORE MC - HAVELOCK, ONTARIO

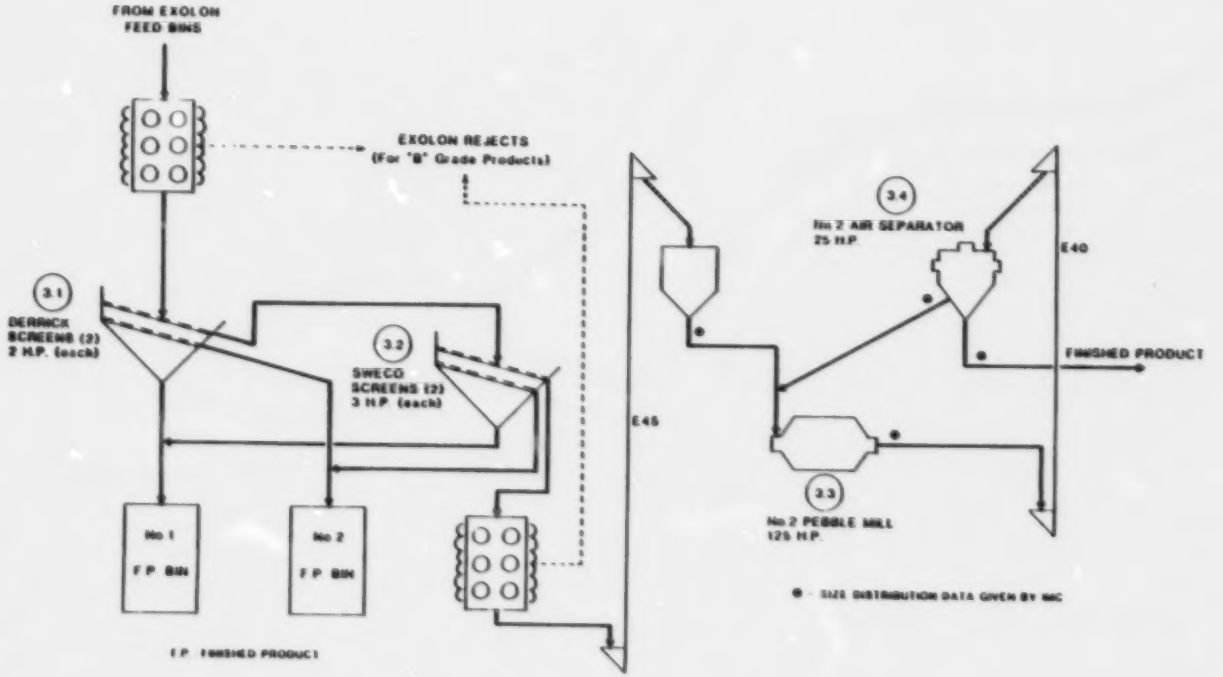
PROJECT No. 20010

Fine Grinding

Fine grinding involves No. 2 and 3 pebble mills. No. 2 pebble mill circuit is shown schematically on page 110. Rated power and average demand of the equipment are summarized on the sketch.

The **particle size distribution** of the feed and product of the mill circuit are summarized as follows.

	% Passing	
Size (μm)	Feed	Product
850	100	-
600	96	-
500	66	-
425	36	-
300	4	-
250	2	-
106	-	-
75	-	100
45	-	99
30	-	89
20	-	67
10	-	38
6	-	25
2	-	12



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
3.1	3'x10' Derrick Screens(2)	1.6
3.2	Sweco Screens (2)	-
3.3	#2 Pebble Mill	75
3.4	#2 Separator	8

CANADA CEMENT LAFARGE LTD.
MONTREAL

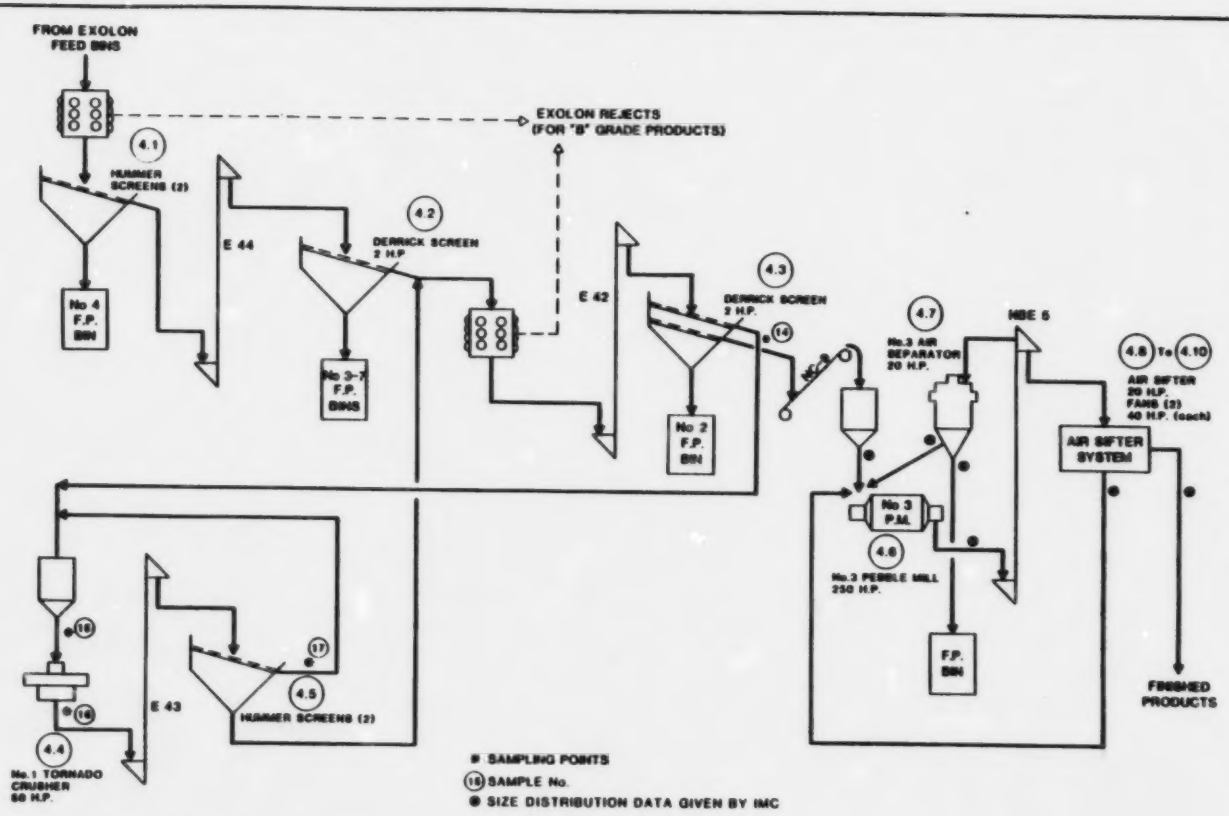
DRAWN GF.J DATE 22/08/83	No.2 PEBBLE MILL CIRCUIT FLOW DIAGRAM	PLANT N° BICORE MC - HAVELOCK, ONTARIO
CHECKED DCB DATE 29/08/84		PROJECT No. 20010

No. 3 pebble mill circuit is shown schematically on page 112. Rated power and average demand are summarized on the sketch.

Circuit feed and separator fines are characterized as follows.

	% Passing	
Size (μm)	Feed	Product
850	100	-
600	97	-
500	73	-
425	47	-
300	14	-
250	9	-
106	-	-
75	-	100
45	-	98
30	-	93
20	-	81
10	-	55
6	-	39
2	-	19

The flowrates for the pebble mill circuits were supplied by IMC.



* SAMPLING POINTS
(10) SAMPLE No.
● SIZE DISTRIBUTION DATA GIVEN BY IMC

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
4.1	4'x15' Hummer Screens(4)	3.2
4.2	4'x10' Derrrick Screen	0.8
4.3	3'x10' Derrick Screen	0.8
4.4	#1 Tornado Crusher	28
4.5	4'x10' Hummer Screens(2)	1.6
4.6	#3 Pebble Mill	183
4.7	#3 Air Separator	7
4.8	Air Sifter - Apex 700	6
4.9	Fan #1	12
4.10	Fan #2	15

CANADA CEMENT LAFARGE LTD.
MONTREAL

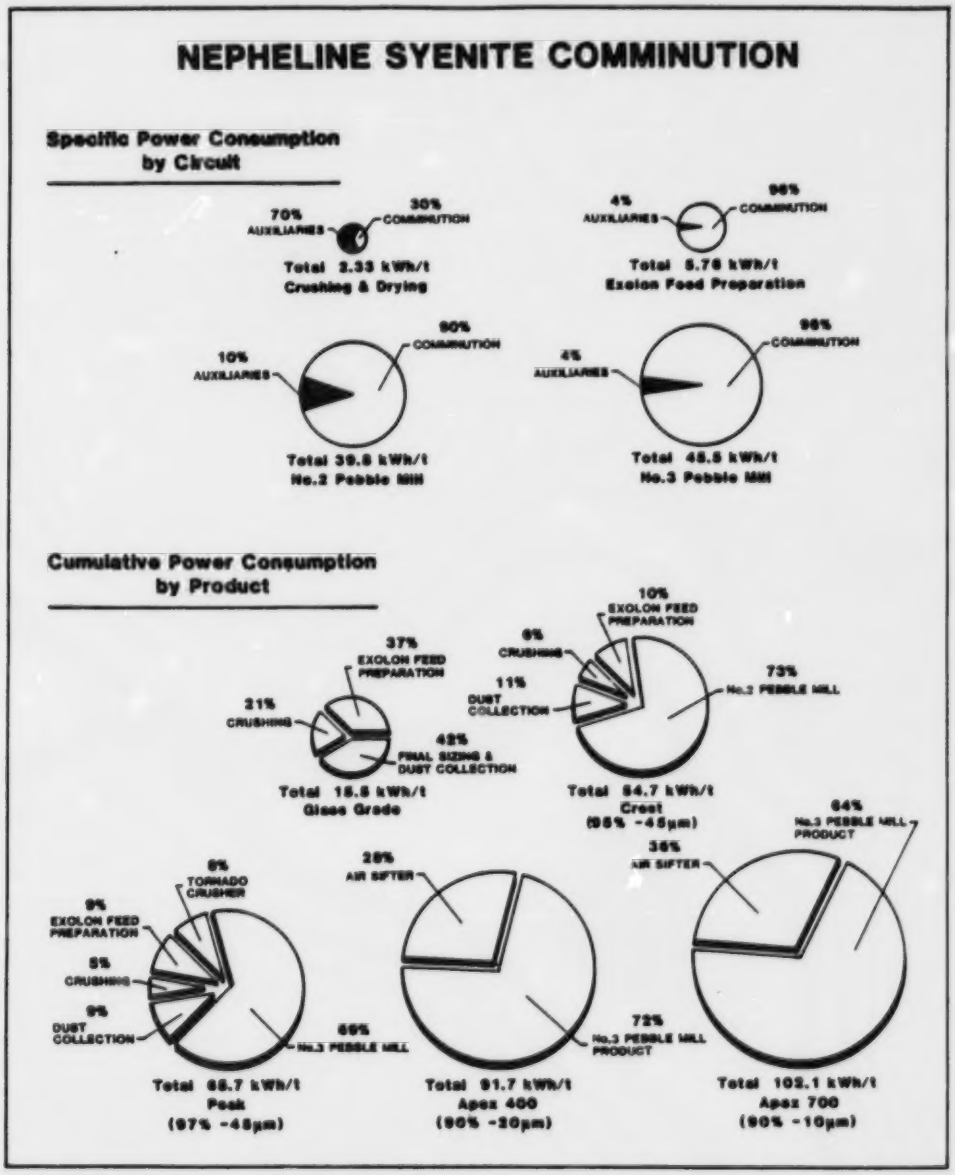
DRAWN FGM DATE 23/09/83
CHECKED DCS DATE 29/09/84

No 3 PEBBLE MILL CIRCUIT FLOW DIAGRAM

PLANT OF IMC - HAVELOCK, ONTARIO
IMCORE DIVISION
PROJECT No: 20010

Results

The specific energy consumption in the crushing and grinding circuits is summarized in the following diagram.



Cumulative specific consumption for finished products includes an allowance for an overall yield of 72% in the process, up to and including, the Dings magnetic separators. Material is rejected from the process by dust wasting. Material rejected by the Exolon magnetic separators is not wasted but downgraded

to "B" products.

Other than in the crushing and drying circuit, plant dust collectors are not generally dedicated to any one machine or circuit. Thus, an overall consumption of 5.9 kWh/t was determined, based on electrical measurements on the dust collectors in question and the total plant production rate. This figure is included in all cumulative specific energies.

Final sizing of glass grade products includes screening and 25% of the tornado crusher demand. Pebble mill products show the majority of their consumption from the fine grinding stage of the process. Cumulative consumption for No. 3 pebble mill product includes 75% of tornado crusher demand.

Conclusions

Consumption by auxiliaries is significant in the crushing and drying circuit. Auxiliary consumption arises mainly from the dryer drive and I.D. fan. Comminution comprises the major portion of specific consumption in the other circuits. Specific consumption is higher in circuits involving high fineness.

Cumulative consumption for the filler (Apex) products shows that the air sifter classification stage adds a considerable amount of consumption to the product. The air sifter involves classification only.

At the time of the study, the plant was operating under typical conditions. These results are considered to provide a representative "snapshot" of comminution consumption in the nepheline syenite industry.

Recommendations

Test the efficiency of autogenous milling to reduce the number of comminution stages.

POTASH

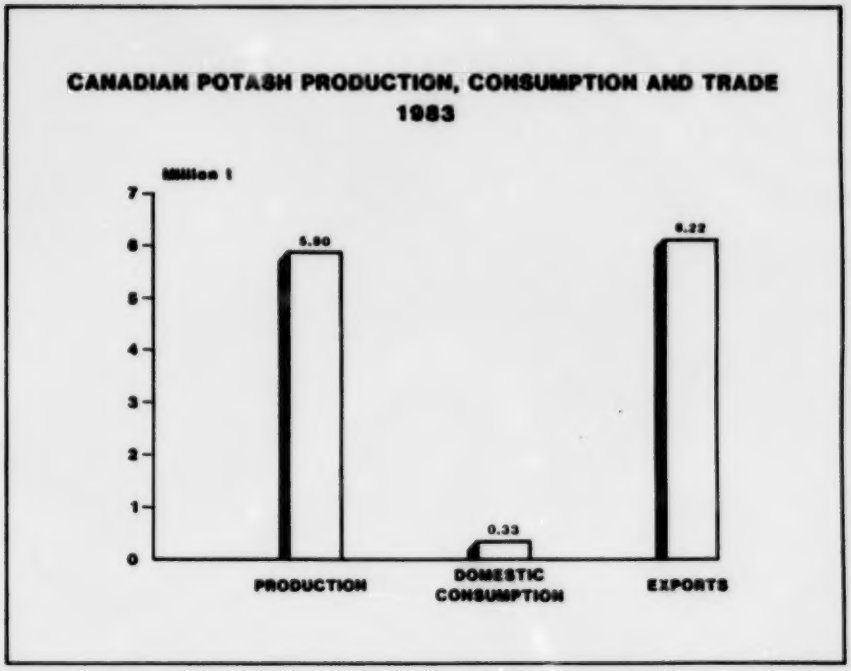
Participating Company

P.C.S. MINING LTD.
Cory Division

Plant Location

Saskatoon, Saskatchewan

Potash: Comminution plays minor role



Source: Canadian Mining Journal, February 1984.

Comminution power requirement : 6.1 kWh/t.

Estimated comminution power requirement by the potash industry in 1982 : 40,200,000 kWh.

Background

Potash was discovered in Canada in the 1940's and limited production took place in the 1950's. The high growth years occurred in the next decade with Canada becoming the world's second largest producer, after the U.S.S.R., by 1968.

The potash industry is located mainly in Saskatchewan. However, potash production has recently begun in New Brunswick.

Canada exports 95% of its production. The United States accounts for 70% of total exports.

Products and Uses

Potash is a source of potassium which is one of the major elements required for plant growth. Thus, 90% of potash is in fertilizers.

It is marketed in Canada in the form of potassium chloride (KCl) called muriate of potash with a chemical composition of:

Typical Chemical Composition of Muriate of Potash	
	%
K	50.5
Mg	0.17
Ca	0.02
Na	1.05
Cl	47.86
SO_4	0.04
Insoluble	0.30

Potash is also sold in a refined form for industrial uses.

The marketed products are classified according to size as follows:

Representative Particle Size Ranges of Potash Products	
Product	Size Range (mm)
Granular	0.8 - 3.4
Coarse	0.6 - 2.4
Standard	0.2 - 1.7
Soluble	0.15 - 0.4
Suspension	0.075 - 0.4
Refined KCl	fine

The Production Process

Potash ore occurs as a mixture of halite (sodium chloride) and sylvite (potassium chloride). The two compounds are present as distinct crystals with some clay adhering to the crystal surfaces.

In the production process, ore is reduced by crushing and grinding to a sufficiently small size to separate the individual crystals. The ore is then scrubbed to remove the clay. Sylvite and halite are separated in a flotation process and the halite sent to tailings. The sylvite is centrifuged and dried before classification into the various products. The coarsest product is produced by a special operation called compaction, wherein crystals of sylvite are "pressed" together to form a coarser material. Final classification is done by screening. These are referred to as "pink" products, due to the color imparted by some remaining impurities.

More highly refined potash products are made in a special crystallizing operation. The process is temperature dependent and requires tight control to recover a basically pure KCl product. Refined material from crystallization is referred to as "white" product.

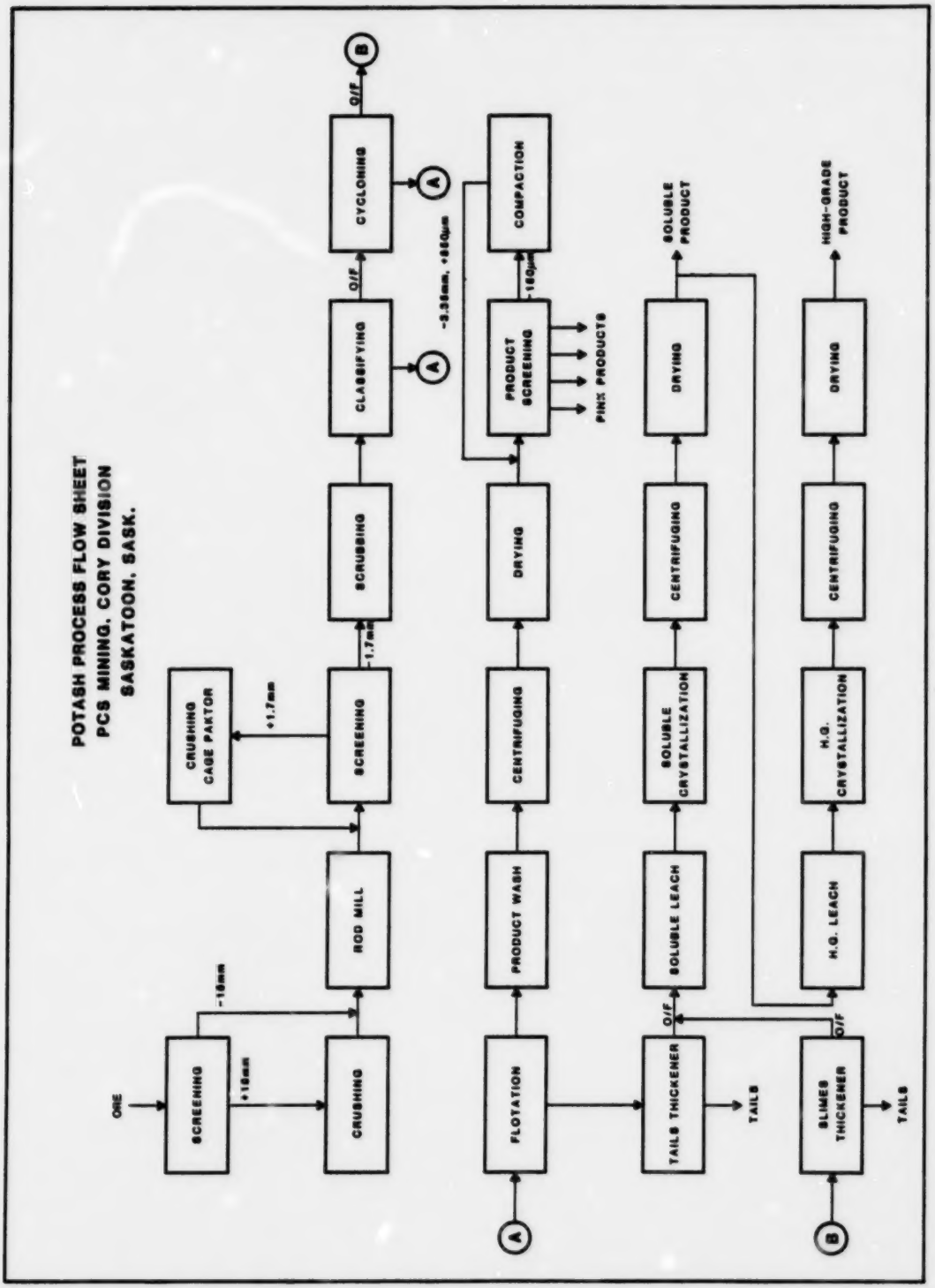
A typical process flow sheet is shown overleaf.

The Role of Comminution

There are two stages involving comminution in the potash process.

Crushing, where mined ore is reduced to a size suitable for scrubbing and flotation.

Post-compaction Crushing, where compacted flake is crushed to product specification.


POTASH PROCESS FLOW SHEET
PCS MINING, CORY DIVISION
SASKATOON, SASK.
ORE
SCREENING
-16mm
+16mm
CRUSHING
ROD MILL
CRUSHING CAGE PAKTOR
+1.7mm
SCREENING
-1.7mm
SCRUBBING
CLASSIFYING
O/F
A
CYCLONING
O/F
B
-2.36mm, +850µm
FLOTATION
PRODUCT WASH
CENTRIFUGING
DRYING
PRODUCT SCREENING
-150µm
COMPACTION
PINK PRODUCTS
A
TAILS THICKENER
O/F
SOLUBLE LEACH
SOLUBLE CRYSTALLIZATION
CENTRIFUGING
DRYING
SOLUBLE PRODUCT
TAILS
SLIMES THICKENER
O/F
H.G. LEACH
H.G. CRYSTALLIZATION
CENTRIFUGING
DRYING
HIGH-GRADE PRODUCT
B
TAILS

Comminution at Cory Division

The Crushing Circuit

The crushing circuit is shown schematically on page 120. Rated power (HP) and average demand (kW) in operation are summarized on the sketch.

The average **production rate** of the crushing circuit is 450 t/h, based on plant records.

Grindability testing resulted in a Bond Index of 13.55 kWh/T and a Hardgrove Index of 55.

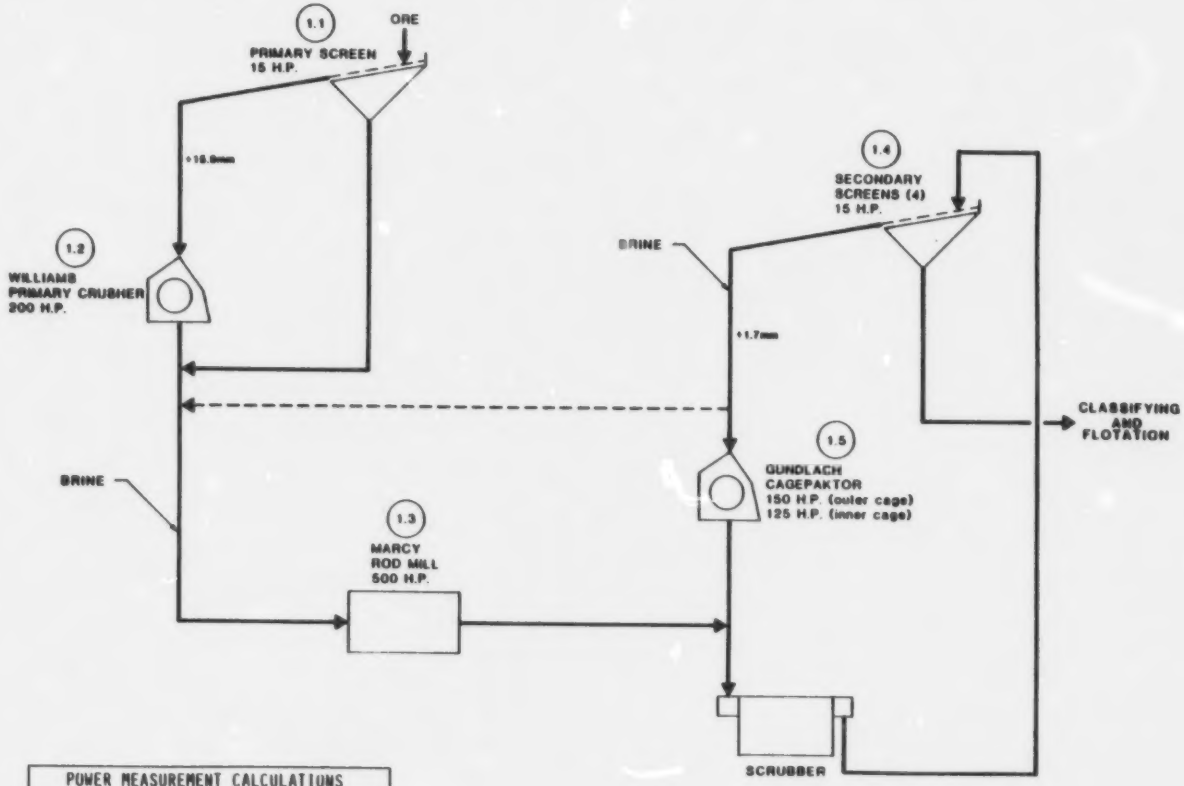
Particle size distribution of ore fed to the circuit and Cagepaktor discharge are characterized in the following table.

	% Passing	
Size	Ore	Cagepaktor Discharge
32.0 mm	100	
18.9	88.0	
9.42	77.2	100
4.75	64.0	98.5
2.36	48.9	78.6
1.40	34.1	39.9
850 µm	28.7	30.1
500	18.1	15.2
250	10.3	8.2
106	4.8	4.5

Post-compaction Crushing

The product screening and compaction circuit is shown schematically on page 121. Rated power and average demand are summarized on the sketch.

The estimated **flowrate** for the circuit is 150 t/h.



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
1.1	PRIMARY SCREEN	4.7
1.2	WILLIAMS PRIMARY CRUSHER	127
1.3	MARCY ROD MILL	370
1.4	SECONDARY SCREENS (4)	3.7
1.5	CAGEPAKTOR	
	OUTER CAGE	73
	INNER CAGE	47

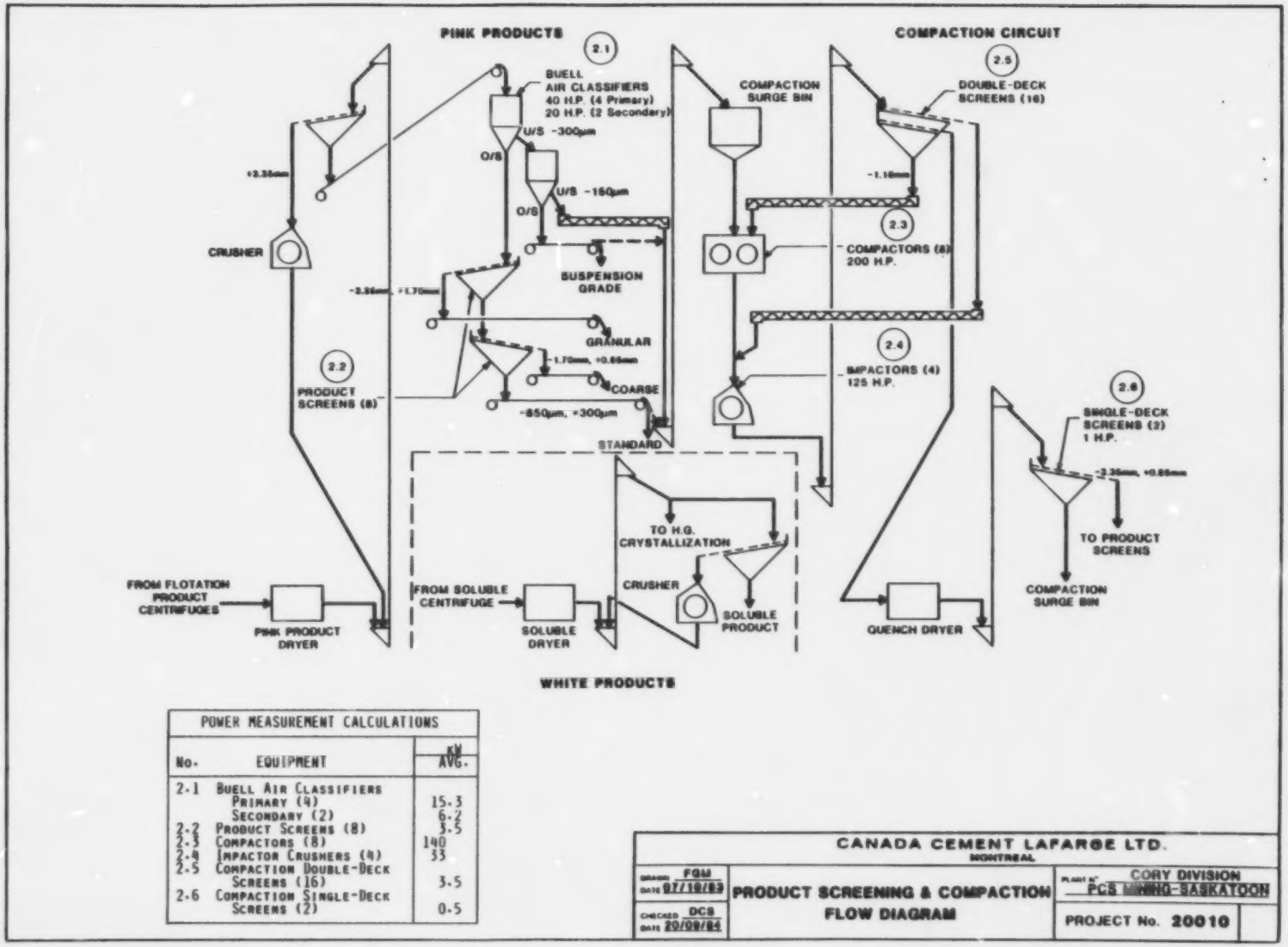
CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN GFJ DATE 3/04/84
CHECKED DCS DATE 20/09/84

ORE CRUSHING FLOW DIAGRAM

PLANT OF CORY DIVISION
PCS MINING - SASKATOON

PROJECT No. 20010



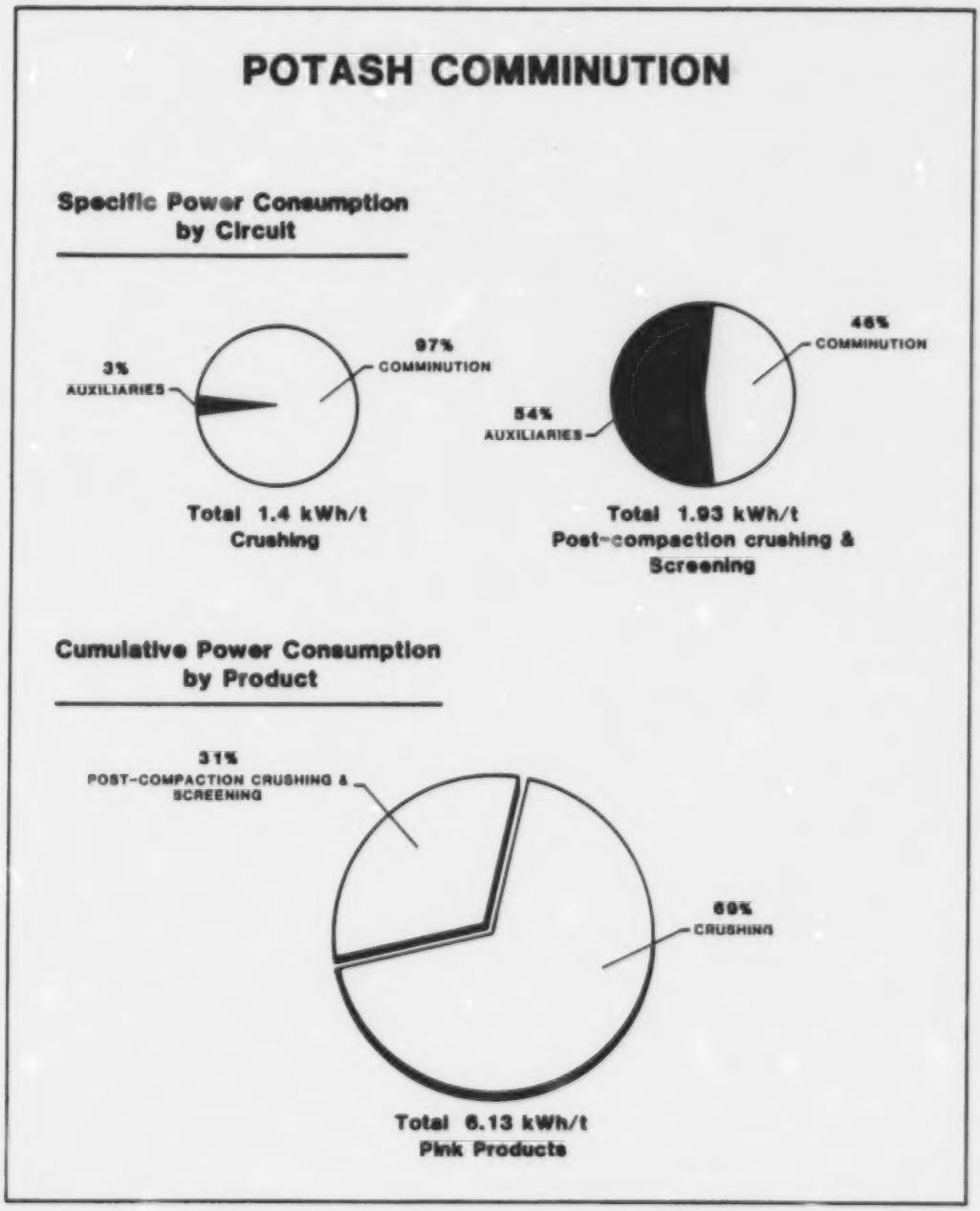
POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
2.1	BUELL AIR CLASSIFIERS	
	PRIMARY (4)	15.3
	SECONDARY (2)	6.2
2.2	PRODUCT SCREENS (8)	5.5
2.3	COMPACTORS (8)	140
2.4	IMPACTOR CRUSHERS (4)	33
2.5	COMPACTION DOUBLE-DECK SCREENS (16)	3.5
2.6	COMPACTION SINGLE-DECK SCREENS (2)	0.5

CANADA CEMENT LAFARGE LTD.
MONTREAL

DRAWN FGW DATE 07/10/83	PRODUCT SCREENING & COMPACTION FLOW DIAGRAM	PLANT OF CORY DIVISION PCS MINING-SASKATOON
CHECKED DCS DATE 20/09/84		PROJECT No. 20010

Results

Specific energy consumption for comminution and associated operations in potash processing is summarized in the following diagram.



Specific consumption is reported only for pink products. Processing of white products is mainly by solution involving no comminution.

Consumption for compaction was calculated to be 7.5 kWh/t of finished product. This is not included in the cumulative power consumption since compaction is, in a sense, the opposite of comminution.

Conclusions

The consumption for comminution and auxiliaries is low. Practically all consumption in the initial crushing circuit is for comminution, while for post-compaction crushing and product screening, comminution accounts for a much smaller proportion. This is a result of the large number of screens and the air classifiers.

Crushing circuit consumption accounts for a major portion of product cumulative specific energy. This is due to the fact that the yield in the flotation circuit is 33%, requiring 3 tonnes of ore to be crushed for each tonne of product.

Considering the light loading of the four crushers in the compaction circuit, it may be more efficient to use two of the crushers at a time for processing. This would also facilitate maintenance by freeing two crushers as back-ups.

In summary, comminution is not a major energy consumer in the potash process.

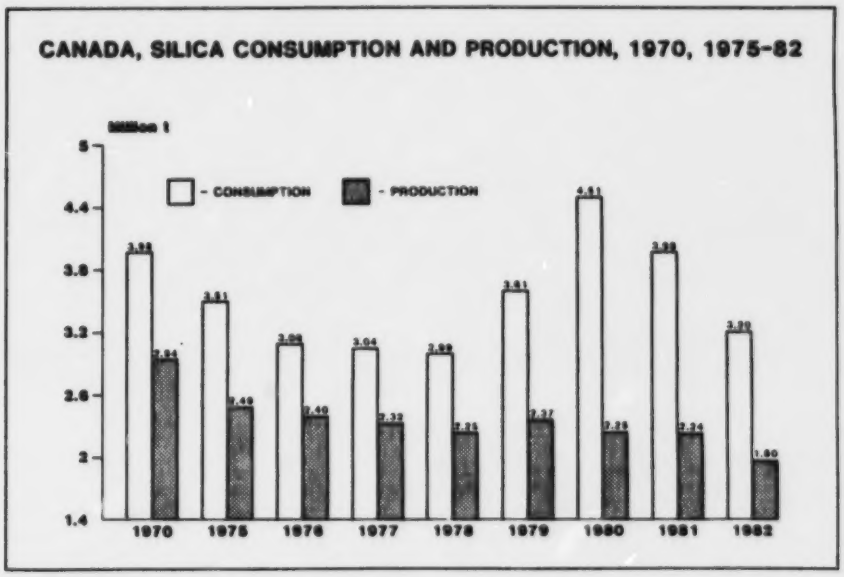
Recommendations

None.

SILICA

Plant closures and competitive market pressures resulting from the recession made it impossible to visit a producing silica operation. The Phase I data base information was assembled from published literature and discussions with operators and consultants.

Silica: Variable specific power consumption - high tonnages



Source: Canadian Minerals Yearbook 1982, EMR Canada.

Comminution power requirements :

ferro silicon grades	- 1.3	kWh/t.
glass sand grades	- 22.9	kWh/t.
ceramic & fiberglass grades	- 115-175	kWh/t.

Estimated comminution power requirement by the Canadian silica industry : 35,000,000 kWh/yr.*

Background

Production from the Canadian silica industry has decreased since 1979 due to reduced demand from the major consumers, i.e., the steel and base metal industries, housing, automobile and container industries. Ontario and Quebec account for 65-70% of total production, and most of this by a single company. In addition to eleven quartz-silica sand producers, numerous companies in the ferrous, base metal and cement sectors also process silica for their in-house needs.

* Assumes distribution of 75% lump and flux, 15% glass and 10% fine ground.

Products and Uses

Silica is consumed in a variety of industries as shown in the table below.

CANADA - ESTIMATED CONSUMPTION OF SILICA, BY INDUSTRIES		
	1981 (tonnes)	%
Foundry sand	1,085,481	27
Glass manufacture (including glass fibre)	951,442	24
Smelter flux[1]	837,203	21
Refractory brick mixes, cements	359,163	9
Artificial abrasives	125,706	3
Metallurgical	143,447	4
Chemicals	39,430	1
Gypsum products	2,314	-
Concrete products	211,608	5
Fertilizer, stock poultry feed	3,982	-
Other[2]	223,975	6
TOTAL	3,983,751	100

Source: Statistics Canada; Energy, Mines and Resources, Canada.
[1] Producers' shipments of quartz and silica for flux purposes.
[2] Includes asbestos products, ceramic products, frits and enamels, paper and paper products, roofing and other minor uses.

Approximately one million tonnes per annum of silica sand enters Canada for use in the glass and foundry industries. These sands compete with Canadian grades due to their lower operating and transportation costs. Furthermore, these U.S.A. sands have a narrow size range of rounded grains; qualities heretofore unattainable from quartzite deposits in Canada, yet required for foundry sand applications.

Price per tonne of silica at the processing mine and mill vary from $1 for flux grade, to $5-10 for ferrosilicon grades, to $30-35 for glass grades, to $40-50 for ceramic and filter grades. Transportation costs of the finished product to the customer can be in the same magnitude as the selling price and is therefore a key component in the marketing of a mines product.

The chemical and particle size specifications of a silica product vary considerably and are set by the market. A typical quartzite deposit and its products would have the following chemical composition;

CHEMICAL COMPOSITION	%
SiO_2	98.7
Al_2O_3	0.6
Fe_2O_3	0.04
CaO	0.005
MgO	0.015
K_2O	0.015
Na_2O	0.013
TiO_2	0.02
LOI	0.15

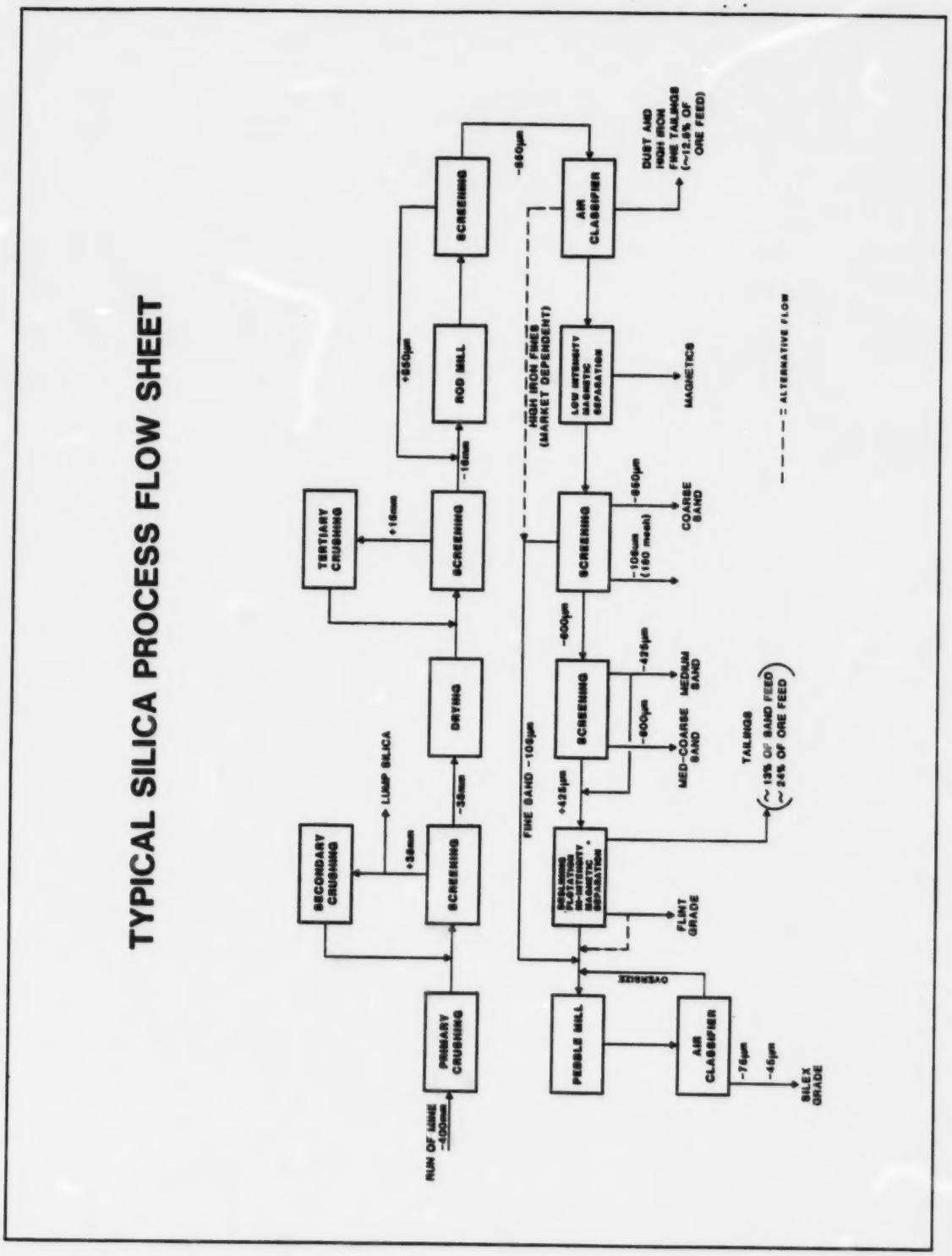
The size specifications for the principal products are -90 +40 mm for lump silica, -700 +74 μm for glass sand, -74 μm for asbestos cement silica and -45 μm for cleanser and ceramic grade silica.

The Production Process

A typical process flow sheet is shown overleaf.

The process is highly dependent upon the market being served and by the characteristics of the quartz-silica sand orebody. We have attempted to describe a typical process treating a quartzite deposit for the ferrosilicon, glass, fiberglass, ceramic and filler markets. The process involves crushing-screening and drying to produce lump silica for ferrosilicon use; followed by coarse rod mill grinding - screening - air classification and magnetic separation for regular glass grade products; followed by flotation - drying and high intensity magnetic separation for premium glass grade products; followed by pebble mill grinding and classification for ceramic, filler and fiberglass grade products.

TYPICAL SILICA PROCESS FLOW SHEET



The Role of Comminution

There are three comminution steps in silica processing.

Crushing, where ore is reduced and dried to make a lump silica product and feed for primary grinding.

Primary grinding and classification, where crushed material is ground, classified to remove abraded iron and screened into various glass grades and feed to flotation and fine grinding.

Fine grinding, where sand is ground and classified to make various products.

Comminution in a Typical Silica Operation

The Crushing Circuit

The typical circuit is shown schematically on page 129.

A lump silica product (-90 +40 mm) for the ferrosilicon market could be removed prior to the drying stage.

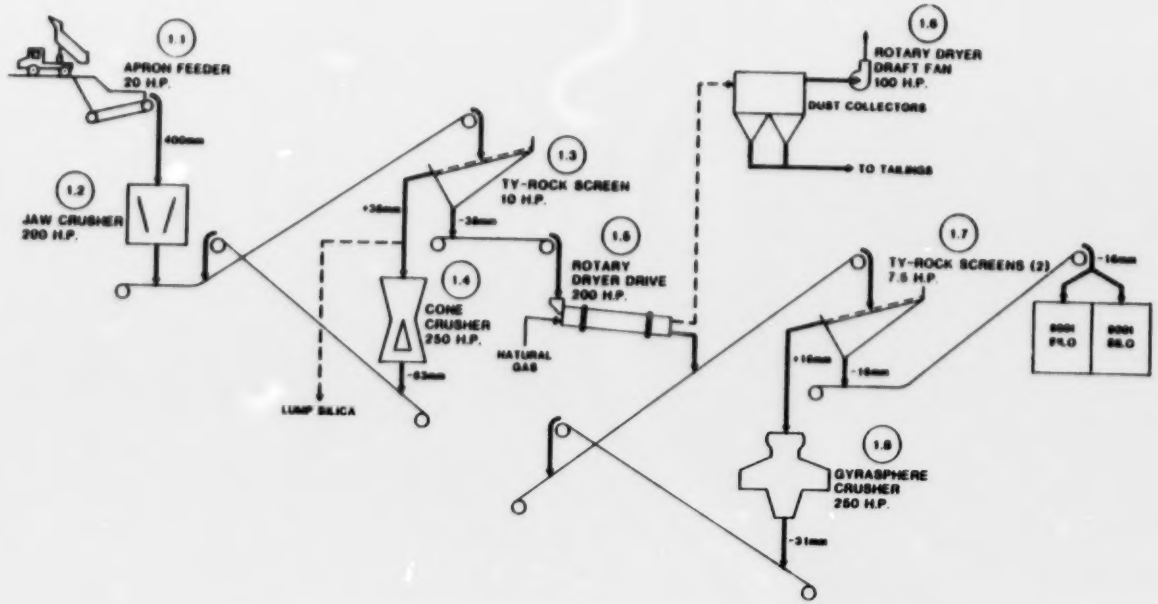
The circuit has 3 stages of crushing with intermediate screening and a drying stage, to produce -16 mm feed to the primary grinding circuit.

The production rate of the circuit is taken as 135 t/h.

Primary Grinding and Classification

This typical circuit is illustrated on page 130.

The dry grinding circuit consists of a rod mill operating in closed circuit with screens, the undersize of which is air classified to remove a fine fraction that is also high in iron



NOTE: 2 Dust Collectors (not shown) 2 X 50 H.P.

POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
1.1	Apron Feeder	8
1.2	Jaw Crusher	50
1.3	Ty-Rock Screen - 5'x12'	4
1.4	5-1/2' Cone Crusher	100
1.5	Rotary Dryer Drive	75
1.6	Rotary Dryer Draft Fan	58
1.7	Ty-Rock Screen - 4'x12' (2)	3
1.8	Gyrasphere Crusher	150
1.9	Crushing Plant Dust Collector	29
1.10	Screening Plant Dust Collector	33

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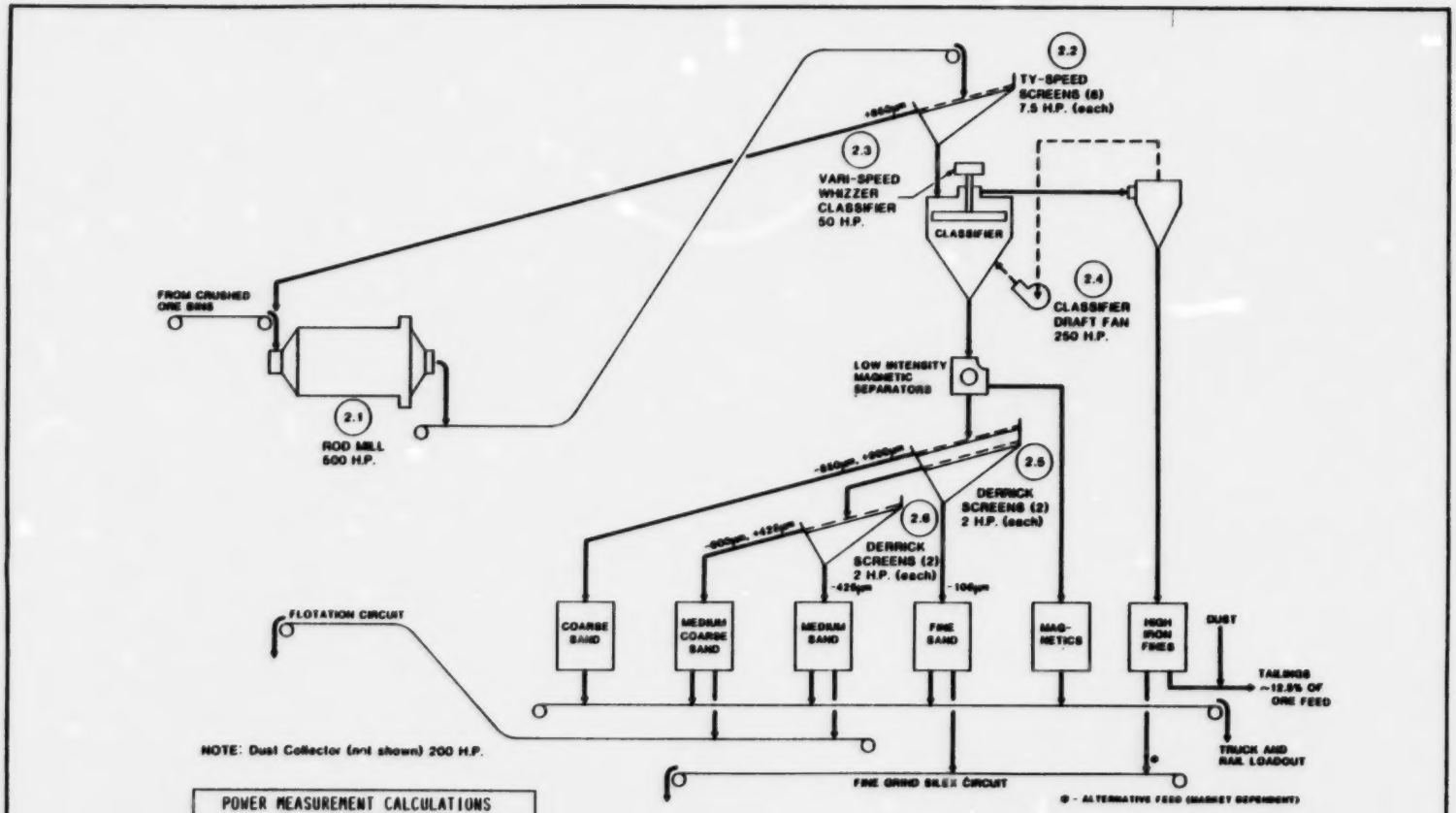
CRUSHING AND DRYING
TYPICAL FLOW DIAGRAM

PLANT N° ____

PROJECT No. 20010



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	kW AVG.
2.1	Rod Mill - 11.5' x 14'	300
2.2	Ty-Speed Screen - 4' x 10' (8)	3.5
2.3	Vari-Speed Whizzer Classifier	25
2.4	Classifier Draft Fan	170
2.5	Derrick Screen - 4' x 10' (2)	1.5
2.6	Derrick Screen - 4' x 10' (2)	1.5
2.7	Dust Collector	122

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DRAWN GFJ DATE 16-05-84	PRIMARY GRINDING & CLASSIFICATION TYPICAL FLOW DIAGRAM	PLANT n°
CHECKED DCS DATE 20/09/84		PROJECT No. 20010

from the abrasion of the steel grinding media. The abraded iron in the classifier sand fraction is removed by low intensity magnetic separators. The cleaned sand is screened into various sizes for the glass grade products and for feed to the flotation circuit or fine grind circuits.

The throughput is taken as 40 t/h.

Flotation Circuit

There is no comminution equipment in this circuit. The circuit is described to complete the process.

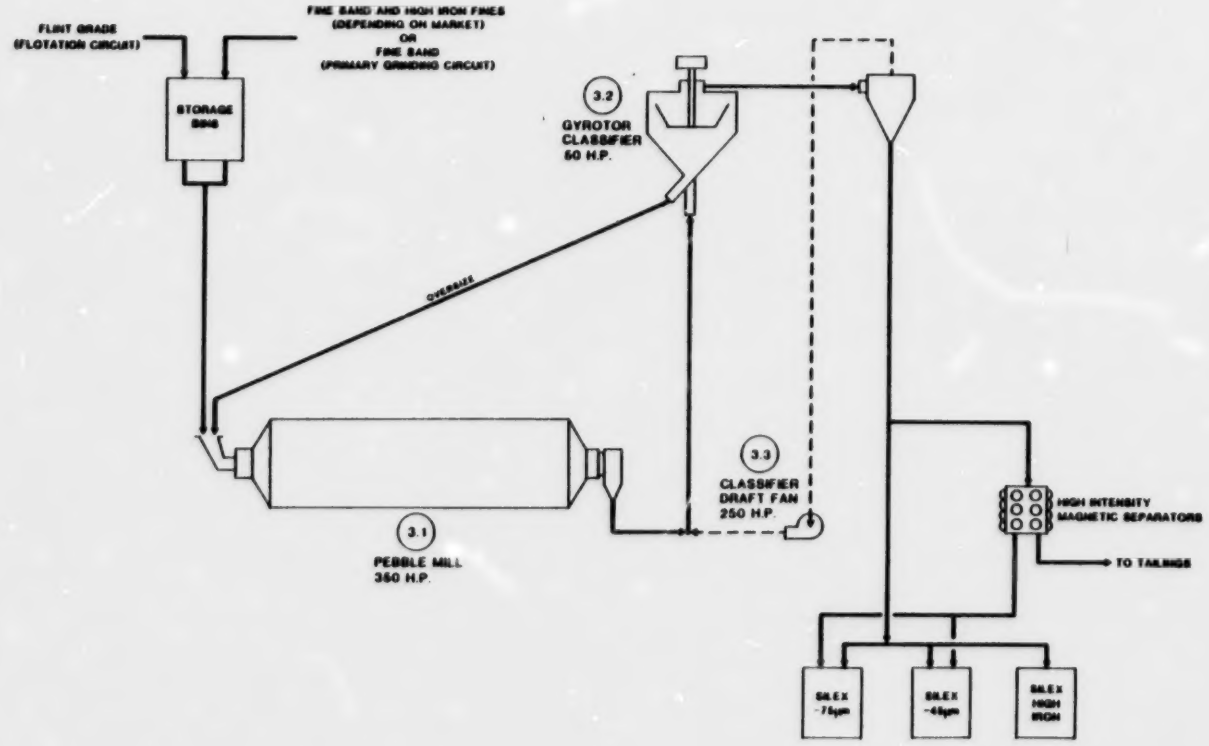
Sized products from the sand circuit can be processed through wet attrition scrubbers, followed by cyclones to remove a slime clay contaminant. The underflow fraction is conditioned with petroleum sulphonate, sulphuric acid, pine oil and xanthate, to remove iron oxides and sulphides in the subsequent flotation circuit. This process reduces the iron content from approximately .05 to .02% Fe_2O_3 and reduces and stabilizes the Al_2O_3 and CaO content. This sand is then filtered, dried and screened into premium glass grade products.

Fine Grinding Circuit

The circuit is illustrated on page 132.

Dry fine sized sand from the previously described circuits is ground using ceramic grinding media in pebble mills operating in closed circuit with air classifiers. Variation in the feed size, feed rate and classifier settings, result in products of various particle sizes. The iron content can be further reduced through the use of high intensity magnetic separators.

The production rate of the circuit is 4.5 t/h for Silex 200 and 2.7 t/h for Silex 325.



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
3-1	Pebble Mill - 7' x 26'	200
3-2	Gyrotor Classifier	35
3-3	Classifier Draft Fan	170

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DRAWN GFJ DATE 17-06-84
CHECKED DCB DATE 29/09/84

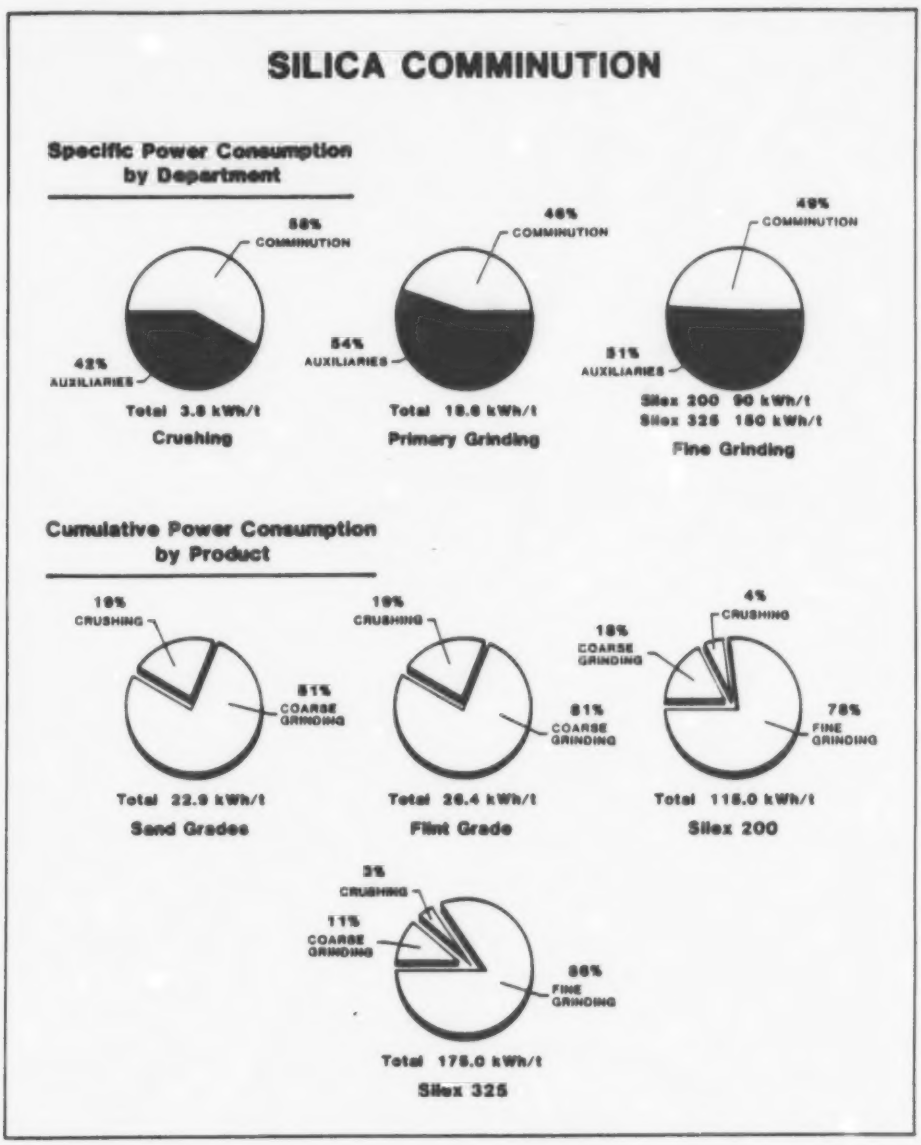
FINE GRINDING
TYPICAL FLOW DIAGRAM

PLANT N° _____

PROJECT No. 20010

Results

The energy used in each of the individual three circuits, i.e., crushing, primary grinding and classification, and fine grinding, and cumulative energy used to produce the principal products from these circuits is shown in the following diagram.



The energy per tonne of product for a 1000 tonnes per day process would vary between 30-50 kWh/t and would depend on the

product mix, the tonnage rate, humidity and recovery.

The Bond Work Index, expressed as the amount of energy required to grind a tonne of quartzite from infinite size to 80% passing 75 µm, is 26 kWh/Ton. The inefficiencies with pebble mill grinding are evident by the comparison of this theoretical value to the industry consumption of 44 kWh/tonne for comminution of the same product.

Conclusions

The industry has yet to install monitoring and controlling devices required to measure throughput and energy consumption rates. Without this instrumentation, there is little possibility in lowering unit energy consumption.

The industry is operating at 60-80% of capacity and is therefore unlikely to make the necessary commitments to promote the research and development and the capital expenditures required for improved fine grinding and classification equipment.

Recommendations

Investigate ways of producing a ground silica with rounded grains suitable for the foundry industry.

Fine grinding using roller mills and tower mills may become a viable alternative to the industry accepted pebble mills. Deserving consideration is the use of heated air and grinding aids to improve throughput rates and the use of different air classifier designs and multistage classifiers to reduce circulating loads to the grinding mill.

Investigate the use of multi-stage classifiers in a fully instrumented demonstration plant to reduce the amount of overgrinding in the pebble mill air classifier circuit.

TALC

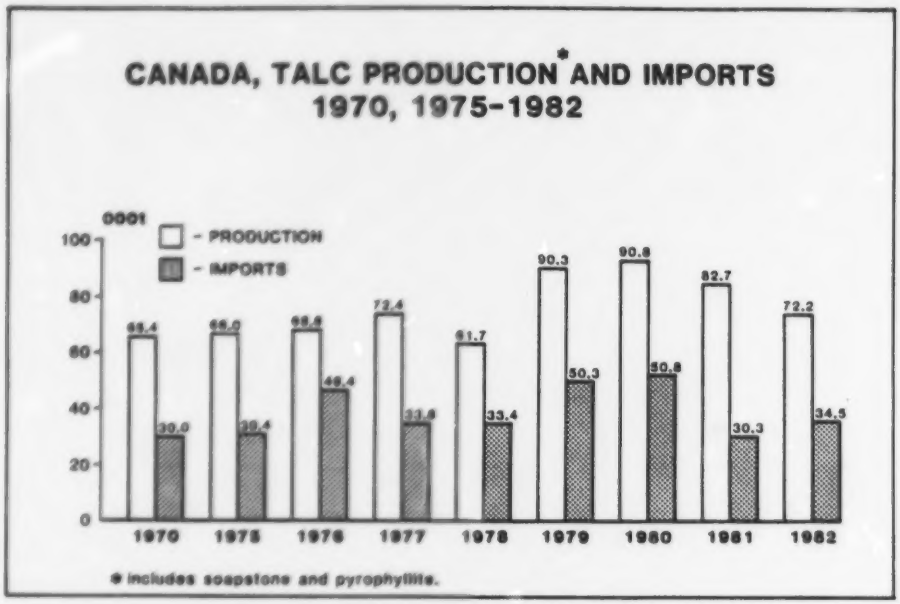
Participating Company

BAKERTALC INCORPORATED

Plant Location

Highwater, Quebec

Talc: High specific power consumption for the micrometer grade but small tonnages



Sources: Minerals Yearbook Centennial Edition 1981.
Mineral Commodity Summaries 1982, EMR Canada.

Specific power consumption for comminution : ground products - 41 kWh/t.
pulverized - 248 kWh/t.

Estimated industry power* consumption for comminution 1982 : 6,000,000 kWh.

Background

The earliest activity in the Canadian talc industry occurred in the 1870's. Since that time numerous deposits have been discovered and some have been worked to varying degrees. Currently, talc is mined by four companies in Canada, two in Quebec and two in Ontario.

Most talc imports are from the United States and are high-quality, high-value materials. It is expected that imports

* Based on a ground to pulverized product ratio of 60:40.

will be replaced somewhat by domestic products as capacity for producing higher grades increases.

Products and Uses

Talc is used mainly as a filler in cosmetics, ceramics, paint, paper, plastics and rubber. Talc products are subject to increasing demands for high purity and quality.

The chemical composition of a typical, relatively high grade industrial talc is presented in the following table.

CHEMICAL ANALYSIS OF INDUSTRIAL TALC
(%)

SiO_2	62.65
Al_2O_3	0.31
Fe_2O_3	-
CaO	Trace
MgO	30.23
$Na_2O + K_2O$	0.20
LOI	4.95
H_2O	4.87
CO_2	0.27

Generally, chemical composition is important insofar as it affects the physical properties. Desirable properties in talc are whiteness, softness and smoothness, coverage, good luster, high "slip", and chemical inertness. Pure talc remains undecomposed in most acids. Chemical composition is controlled by selective mining and by beneficiation during processing.

Talc product fineness is important. Most applications require talc to be -45 μm. The specification for paint is 99.8 to 100 percent -45 μm while, for wall tile, the requirement is 90 percent -45 μm.

Talc sold as paper filler generally meets an average particle size of less than 5 μm and may sometimes be less than 1 μm.

The Production Process

Processing of talc includes crushing and drying talc ore and subsequent fine grinding to product specification. Ground ore may also be subjected to a flotation process to remove impurities. Pulverizing the flotation product can give a super-fine talc for special applications. A typical process flowsheet is shown overleaf.

The Role of Comminution

Three comminution steps are involved in talc processing.

Crushing, where mined ore is dried and reduced to a size suitable for feeding to the mill.

Milling, where crushed ore is ground to the specified fineness of some products (-45 μm) or produced as feed for the flotation circuit. Because of the relative softness of talc, a roller mill is well suited to this application.

Pulverizing, where purified talc from flotation is ground into a superfine product of about 1 μm average particle size. Because of the extreme fineness involved, specialized grinding equipment is required.

Comminution at Bakertalc

The crushing and grinding circuits

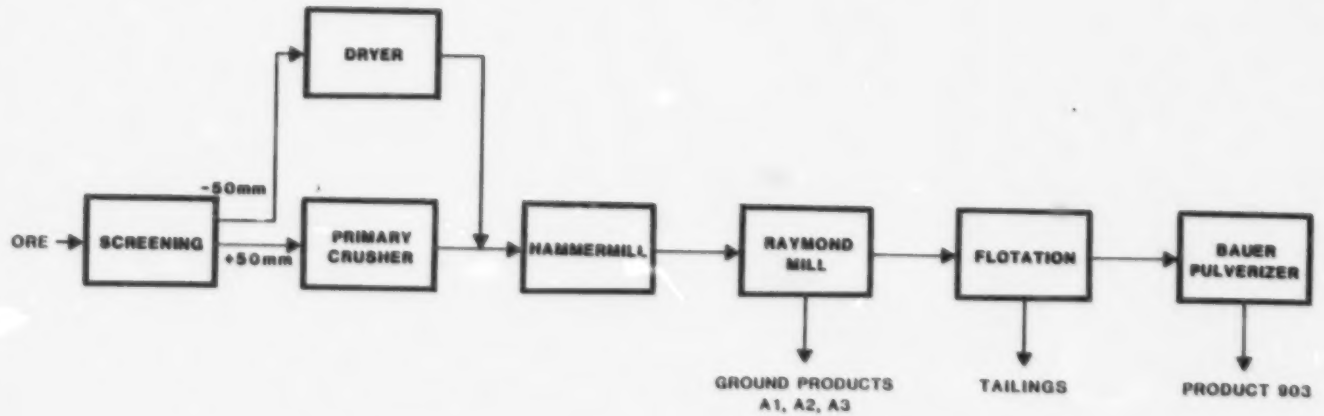
The crushing and grinding circuits are shown schematically on page 139. Rated power (HP) and average power demand (kW) in operation of the various equipment is summarized on the sketch.

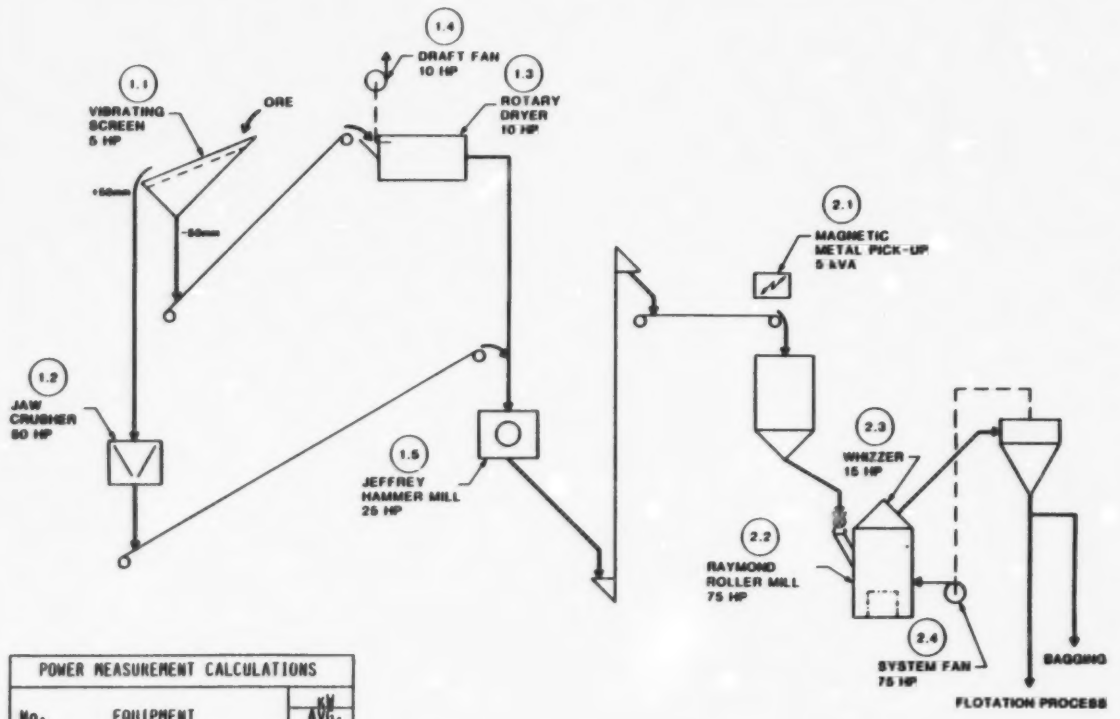
The **production rate** of the crushing circuit was estimated to be 23.6 t/h.

TALC PROCESS FLOW SHEET

BAKERTALC, INCORPORATED

Highwater, Quebec





POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
1.1	Vibrating Screen	-
1.2	Jaw Crusher	10.0
1.3	Rotary Dryer	2.8
1.4	Draft Fan	2.6
1.5	Jeffrey Hammer Mill	7.0
2.1	Magnetic Metal Pick-Up	-
2.2	Raymond Mill	
	Product Al	27.5
	Flotation Feed	22.0
2.3	Whizzer	
	Product Al	8.0
	Flotation Feed	2.5
2.4	System Fan	
	Product Al	56.5
	Flotation Feed	51.0

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DRAWN FQM DATE 84/08/03	CRUSHING AND GRINDING FLOW DIAGRAM	PLANT N° SAKERTALC - HIGHWATER, P.Q.
CHECKED DCS DATE 20/09/84		PROJECT No. 20010

Particle size. Feed material to the crushing circuit was observed to have the following size characteristics:

- Maximum : 300 mm
- Average : 150 - 200 mm
- Minus 5 mm : 40%

Crushing circuit product was found to be minus 63 mm with 75% passing 19 mm.

Grindability testing on a sample of crushed talc ore resulted in a Bond Work Index of 8.35 kWh/T and a Hardgrove Index of 93, indicating a relatively soft material.

Production rate of the Raymond mill varies depending on the material being produced.

- Flotation Feed : 5.0 t/h
- Product A1 : 2.3 t/h
- Product A3 : 1.0 t/h

The **particle size distributions** of Raymond mill products are shown in the following table:

SIZE (μm)	% PASSING		
	FLOTATION FEED	A1	A3
100	98.5	99.0	99.5
70	93.0	97.0	99.0
50	79.5	93.5	99.0
40	70.5	87.0	97.5
20	43.0	34.5	82.0
10	20.0	25.5	35.5
6	10.5	13.5	16.5
2	2.0	3.0	4.0

Pulverizing

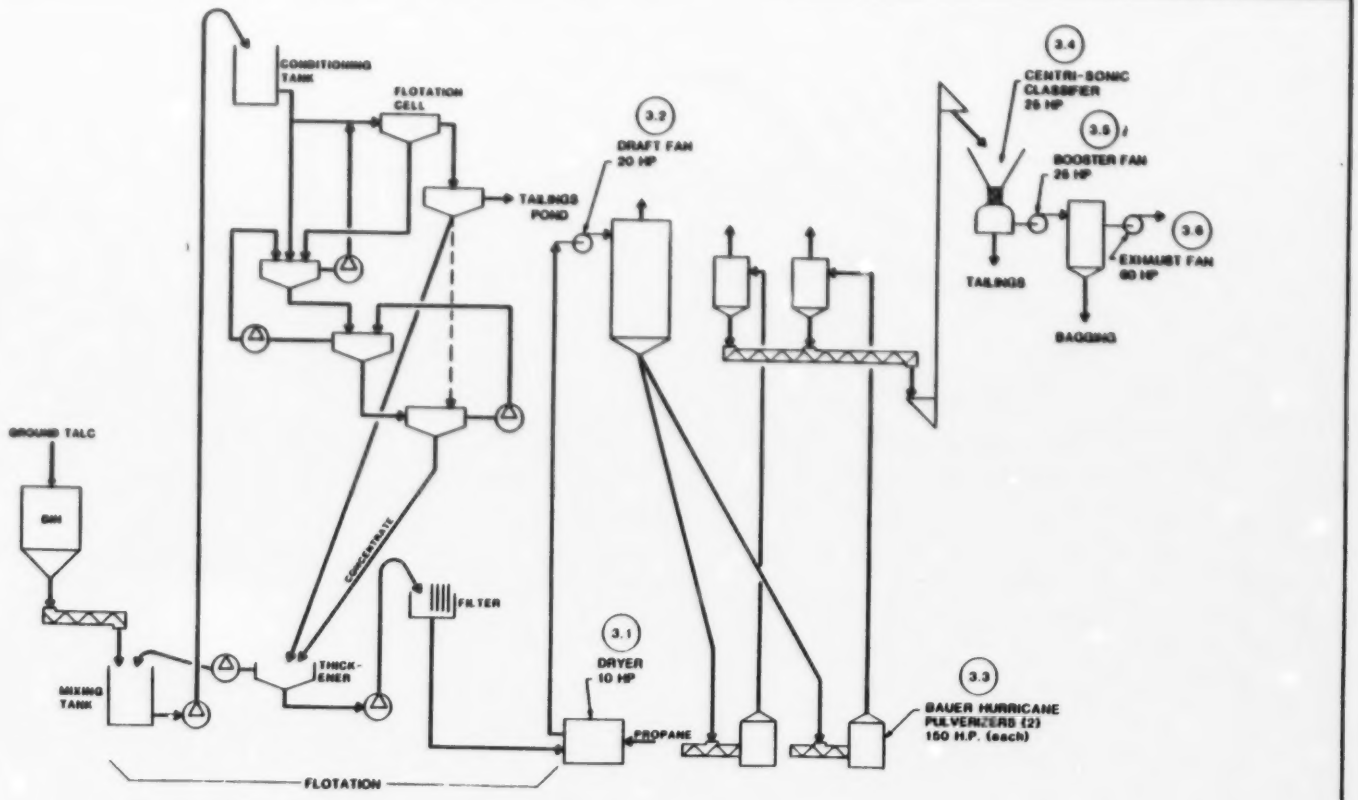
The circuit is shown schematically on page 142. Power demand levels are summarized on the sketch.

The flotation circuit, also shown in the diagram, involves no comminution and is shown only to complete the process. Talc is separated from impurities by adhering to froth bubbles in a talc-water slurry. The product is then filtered and dried. The high iron waste product is pumped to tailings.

The **production rate** of the two pulverizers combined was 0.9 t/h as determined from plant records.

The **particle size distributions** of the pulverizer circuit feed and product are summarized in the following table.

SIZE (μm)	% PASSING	
	FEED	PRODUCT 903
100	100	-
70	97.5	100
50	88.0	99.5
40	79.0	99.5
20	51.0	99.0
10	23.0	94.0
6	10.5	69.0
2	1.5	5.0



POWER MEASUREMENT CALCULATIONS		
No.	EQUIPMENT	KW AVG.
3.1	DRYER	2.8
3.2	DRAFT FAN	10.7
3.3	BAUER HURRICANE PULVERIZER (2) - B1	67.5
	B2	75.5
3.4	CENTRI-SONIC CLASSIFIER	6.0
3.5	BOOSTER FAN	9.6
3.6	EXHAUST FAN	22.3

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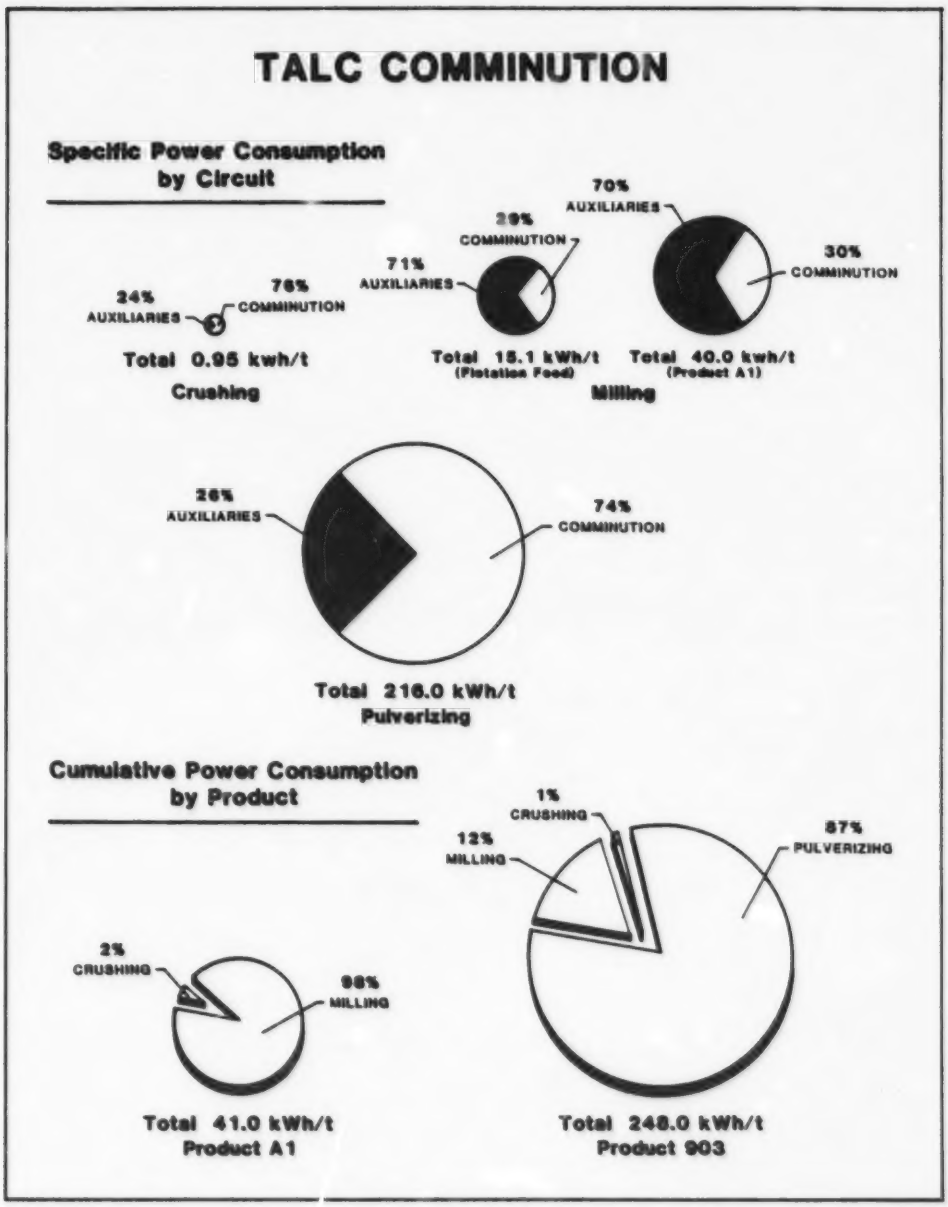
DRAWN FGM DATE 29/09/83	FLOTATION AND PULVERIZING FLOW DIAGRAM	PLANT N° BAKERTALC - HIGHWATER, QUE.
CHECKED DCS DATE 29/09/84		PROJECT No. 20010

Results

The specific energy consumption of the crushing and grinding circuits and cumulative consumption of finished products are depicted in the following diagrams.



The progression of consumption through the process can be seen with higher specific consumption required for finer grinding, rising from 41.0 kWh/t for product A1 (-45 μm) to 248.0 kWh/t for product 903 (-20 μm).

The cumulative consumption for product 903 allows for a 50% yield in flotation. The results demonstrate the importance of operating the pulverizers efficiently. Consumption in primary crushing and drying is very low in all respects.

A relatively small proportion of Raymond mill consumption is made up of comminution energy. Most of the auxiliary energy is consumed by the mill system fan. The low proportion of comminution energy in flotation feed and A1 may be accounted for by the easy grindability of talc.

Conclusions

The Hurricane mill motors were observed to be operating considerably below installed capacity. Increasing the loading of these motors could mean energy savings for this high-consumption area of the process. However, increased feed rate to the pulverizers may result in reduced grinding efficiency and more tailings generated from the classifier. Process studies may serve to optimize this part of the process.

Recommendation

Despite the relative softness of talc, energy consumption for comminution operations, especially for micrometer grade, is high and studies should be directed towards grinding talc in other types of mills.

The minerals are shown below in two different rankings. One is based on annual consumption for comminution and auxiliaries. The figures are derived from typical annual production volumes and specific energy consumption as directly determined during the Phase I data collection. The other ranking is based on average specific energy consumption for products. The averages are weighted depending on the split among the various products for each mineral.

MINERAL RANKING

Industry Comminution Power Consumption		Weighted Average Comminution Power Consumption by Product	
Mineral	kWh/y x 10^6	Mineral	kWh/t *
Cement	570	Mica	290
Asbestos	186	Asbestos	220
Limestone	98	Talc	125
Gypsum	40	Cement	76
Potash	40	Nepheline Syenite	35
Silica	35	Silica	19
Nepheline Syenite	20	Gypsum	18
Lime	6	Potash	6
Talc	6	Lime	2.8
Mica	3	Limestone	2.5

* Weighted average based on product split.

The difference in ranking between the two tables is a result of the size of the respective industries. Limestone, for example, has a low average product consumption since most product is sold as crushed aggregate. However, it ranks high in industry consumption, due to the size of the industry. In contrast, mica, with the highest product consumption, falls at the bottom of the list in industry consumption because of low production volume. Product consumption for cement, combined with relatively high production volumes, makes cement a large consumer of energy for comminution in the industrial minerals sector.

The next table compares power consumption by comminution circuit for each mineral's finest product. The circuit in question represents the final processing stage for that product and, generally, has the highest power consumption of all process stages.

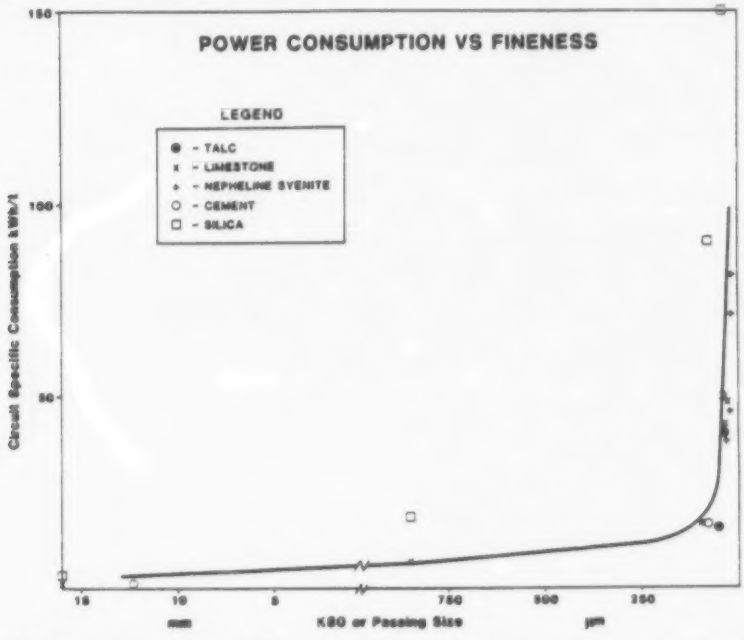
FINE GRINDING CIRCUIT CONSUMPTION

Mineral	Bond Grindability kWh/Ton	Fineness		Circuit Consumption kWh/t	Circuit
		Feed	Product		
Mica	42	-1.7 mm	-45 µm	488	Fluid Energy Mill
Talc	8	80%-41 µm	90%-7 µm	216	Pulverizer
Silica	26	-850 µm	-45 µm	150	Pebble Mill
Asbestos	N/A	N/A	N/A	101	Aspiration
Nepheline Syenite	14	-600 µm	80%-8 µm	82	Pebble Mill
Cement	12	-25.4 mm	80%-40 µm	50	Ball Mill
Limestone	8	80%-40 µm	80%-22 µm	48	Pebble Mill
Gypsum	10	80%-41 mm	80%-83 µm	17	Roller Mill
Lime	4	80%-28 mm	80%-2.4 mm	2.3	Hammer Mill
Potash	14	N/A	-3.35 mm	1.9	Hammer Mill

N/A Not available.

The finenesses shown are those of the feed to the final stage and the product. Where possible, the fineness is reported as the 80% passing size to coincide with the Bond Index which is the energy required to reduce the material from infinite size to 80% passing 75 µm. The energy consumption can be related to the grindability and the degree of size reduction. For a low grindability index and relatively coarse product, e.g. lime, the energy consumption is very low.

The relationship between fineness and energy consumption for a number of minerals is shown in the following figure.



For each mineral, the fineness and power consumption of the intermediate stages and final product were plotted. The fineness is 80% passing size except for silica which is passing size. The energy consumption is seen to increase gradually to 100 µm. As the fineness increases beyond that point, consumption rises very rapidly.

Representative power consumption figures for crushing and grinding are shown below.

POWER CONSUMPTION BY CIRCUIT

Process	Typical Product Size	Typical Power Consumption
Crushing	30 mm	1.5 kWh/t
Grinding	-100 µm	40 kWh/t
	-45 µm	150 kWh/t

As expected, crushing uses considerably less power than grinding, and power consumption in grinding increases markedly with fineness.

The circuit specific energy consumption for all the minerals are summarized in the next table. They are broken down to show the proportion of auxiliary and classification energy. Classification devices range from single or multi-deck screens in coarse grinding circuits to air sifters, air separators, and vari-speed whizzers in fine grind circuits. Generally, the energy requirement for classification is higher in circuits involving high fineness.

CIRCUIT SPECIFIC ENERGY CONSUMPTION

MINERAL	MATERIAL	PASSING SIZE	K80	CLASS. kWh/t	%	AUX. kWh/t	%	TOTAL kWh/t
Talc	Crushed Ore	63 mm	21 mm	0	0	0.2	24	1
	Product A1	100 µm	35 µm	3.5	9	28	70	40
	Flotation Feed	106 µm	50 µm	0.5	3	11	71	15
	Product 903	70 µm	7 µm	6.7	3	57	26	216
Lime	Crushed Stone	50 mm	28 mm	0.1	8	0.4	51	0.8
	3/16" Lime	6.7 mm	2.4 mm	0.5	20	1.5	66	2.3
	Steelworks Lime	N/A	N/A	0.2	100	0.2	100	0.2
	Hydrated Lime	N/A	N/A	0.1	53	0.1	53	0.2
Limestone	Crushed Stone	50 mm	16 mm	0.1	6	0.6	40	1.5
	Agricultural Stone	3.4 mm	850 µm	0	0	0.2	3	6.6
	Filler	300 µm	92 µm	0	0	1.5	9	17
	Product 452	50 µm	26 µm	2.6	6	17	40	42
	Product 441	45 µm	22 µm	3	6	25	53	48
Nepheline Syenite	Crushed Ore	31.5 mm	12.5 mm	0	0	1.6	69	2.3
	Exolon Feed	600 µm	N/A	0.3	4	0.3	4	5.8
	Crest	75 µm	26 µm	3.9	9.8	3.9	9.8	40
	Peak	75 µm	20 µm	1.6	3.5	1.6	3.5	46
	Apex 400	25 µm	13 µm	26	100	26	100	26
	Apex 700	45 µm	8 µm	36	100	36	100	36
Potash	Crushed Ore	1.7 mm	1 mm	0.04	2.9	0.04	2.9	1.4
	Pink Products	3.4 mm	N/A	1.1	55	1.1	55	1.9
Asbestos	Crushed Ore	133 mm	N/A	0.01	2.5	0.1	27	0.5
	Dry Ore	50 mm	N/A	0.2	8	1.2	56	2.2
	Mill Rock	N/A	N/A	0.5	13	0.5	14	3.5
	Fibre	N/A	N/A	—	—	101	100	101
Cement	Crushed Stone	20 mm	12.3 mm	0.2	4.7	0.3	23	1.3
	Raw Mix	600 µm	78 µm	1	6.3	2.3	14	16
	Cement	83 µm	40 µm	3.2	6.4	4.6	9.2	50
Mica	Crushed Ore	1.7 mm	1.4 mm	0.2	4.7	2.3	50	4.6
	Delaminate	1.7 mm	N/A	16	19	55	69	80
	FE Product	45 µm	N/A	4.1	0.8	17	3.5	488
Gypsum	Crushed Ore	75 mm	41 mm	0.01	0 7	1.3	87	1.5
	Ground Gypsum	330 µm	83 µm	0.3	1.7	7.9	47	17
Silica	Crushed Ore	16 mm	N/A	0.03	1.4	1.6	42	3.8
	Ground Sand	850 µm	N/A	6.5	35	10	54	19
	Silex 200	75 µm	N/A	7.8	8.6	46	51	90
	Silex 325	45 µm	N/A	13	8.6	76	51	150

N/A Not available.

Cumulative energy for the finished products is summarized below.

PRODUCT CUMULATIVE ENERGIES				
MINERAL	PRODUCT	PASSING SIZE	K80	kWh/ tonne
Talc	Product A1	100 µm	35 µm	41
	Product 903	70 µm	7 µm	248
Lime	3/16" Lime	6.7 mm	2.4 mm	3.9
	Steelworks Lime	N/A	N/A	1.8
	Hydrated Lime	N/A	N/A	3.6
Limestone	Crushed Stone	50 mm	16 mm	1.5
	Agricultural Stone	3.4 mm	850 µm	6.6
	Filler	300 µm	92 µm	17
	Product 452	50 µm	26 µm	42
	Product 441	45 µm	22 µm	48
Nepheline Syenite	Glass Grade	600 µm	N/A	16
	Crest	75 µm	26 µm	55
	Peak	75 µm	20 µm	66
	Apex 400	25 µm	13 µm	92
	Apex 700	45 µm	8 µm	102
Potash	Pink Products	3.4 mm	N/A	6.1
Asbestos	Fibre	N/A	N/A	223
Cement	Cement	83 µm	40 µm	76
Mica	"Z" Product	1.7 mm	1.4 mm	4.6
	"S" Product	1.7 mm	N/A	85
	"FE" Product	45 µm	N/A	573
Gypsum	Ground Gypsum	330 µm	83 µm	18
	Stucco	330 µm	83 µm	21
Silica	Sand Grade	850 µm	N/A	23
	Flint Grade	850 µm	N/A	26
	Silex 200	75 µm	N/A	115
	Silex 325	45 µm	N/A	175

N/A Not available.

Refining process and the associated generation of waste material contributes to increased product specific energy since larger volumes of unbeneficiated material must be processed per unit of finished product. Of all Phase I minerals, only limestone involved no beneficiation. Process yields ranged from 83% for mica processing to 33% for potash. A very low yield was encountered in asbestos processing where asbestos fibre comprises only 5.5% of dry ore.

The data base includes all Phase I minerals. For each mineral, the name of the participating company and the location of the plant that was visited, are noted. The process information deals with individual circuits. In each case, the circuit is identified, followed by an equipment list, power ratings and measured kilowatts while in operation. Material grindability indices are presented, along with particle size data on process streams. The calculated circuit specific energy consumption is included.

The final entry for a given mineral involves cumulative specific energy consumptions for all finished products. A brief narrative outlines the calculation of cumulative consumption, indicating process yield factors and other relevant information.

All minerals follow the same general format of the following data base sample.

The data file is in place in the CANMET computer system. For information, contact EMR, Office of Technology Transfer.

****
GYPSUM
****

COMPANY/PLANT: DOMTAR CONSTRUCTION MATERIALS LTD. CALEDONIA, ONT.
DATE MEAUSUREMENTS DONE: FEBRUARY 1984

NUMBER OF FINISHED PRODUCTS= 1

NUMBER OF CRUSHING CIRCUITS= 1
NUMBER OF GRINDING CIRCUITS= 1

GYPSUM
CRUSHING CIRCUIT # 1
****

CIRCUIT NAME/MAT. TYPE: ORE CRUSHING AND DRYING

EQUIPMENT LIST

NO.	EQUIPMENT TYPE/MAKE/MODEL	MOTOR HP	MOTOR VOLTS	MOTOR AMPS	OBSERVED KW MAX	OBSERVED KW MIN	OBSERVED KW AVG.
1.1	SIMPLICITY FEEDER - GRIZZLY	30	550	32	8.5	8.5	8.5
1.2	JAW CRUSHER	40	550	41	10.1	10.1	10.1
1.3	WOBBLER FEEDER	10	550	10	2.1	2.1	2.1
1.4	SYMONS CONE CRUSHER	60	550	66	29.7	29.7	29.7
1.5	ASPIRATION FAN	10	575	11.5	10.4	10.4	10.4
2.1	ORE DRYER (GAS)	50	575	48	21.7	21.7	21.7
2.2	DRYER I.D. FAN	60	575	57	26.3	26.3	26.3

BOND WORK INDEX= 10.32
HARDGROVE INDEX= 61.00

OPEN CIRCUIT

SAMPLES:

1 - CIRCUIT FEED
2 - PRIMARY CRUSHER PRODUCT
3 - SECONDARY CRUSHER FEED
4 - CRUSHING CIRCUIT PRODUCT 210 T/H
DRY ORE 41 T/H

SIZE DISTRIBUTIONS (% PASSING)

UM	1	2	3	4
300000	100			
150000	80	100	100	
100000		85	93	
75000			80	100
50000	40	60	20	90
38000				80
25000				60
19000				50
12500				40
4750				20

CIRCUIT PRODUCT SPECIFIC POWER CONSUMPTION (KWH/T)

COMMINUTION: 0.1900E+00
AUXILIARIES: 0.1270E+01

TOTAL: 0.1460E+01 KWH/T

GYPSUM
GRINDING CIRCUIT # 1
****

CIRCUIT NAME/MAT. TYPE: GYPSUM GRINDING

EQUIPMENT LIST

NO.	EQUIPMENT TYPE/MAKE/MODEL		HP	MOTOR VOLTS	AMPS	OBSERVED KW MAX	MIN	AVG.
2.3	RAYMOND ROLLER MILL 6000	#1	150	550	140	135	135	135
		#2	150	550	140	118	118	118
		#3	150	550	140	115	115	115
2.4	WHIZZER CLASSIFIER	#1	10	550	11.2	3.7	3.7	3.7
		#2	10	550	11.2	3.3	3.3	3.3
		#3	10	550	11.2	4.5	4.5	4.5
2.5	MILL FAN	#1	125	550	116	95.2	95.2	95.2
		#2	150	575	145	96.3	96.3	96.3
		#3	125	550	116	103	103	103
2.6	MILL DUST COLLECTOR		60	575	57	17.6	17.6	17.6

BOND WORK INDEX= 10.32
HARDGROVE INDEX= 61.00

OPEN CIRCUIT

SAMPLES:

1 - MILL FEED
2 - MILL PRODUCT 41 T/H (3 MILLS COMBINED)

SIZE DISTRIBUTIONS (% PASSING)

UM	1	2
75000	100	
50000	90.5	
25000	61.9	
12500	40.0	
4750	22.4	
1180	11.4	
425		100
300	5.7	98.8
150	3.8	93.0
106		84.5
75		78.3
45		75.5
30		69.5
20		63.0
10		48.0
6		35.0
2		13.5

CIRCUIT PRODUCT SPECIFIC POWER CONSUMPTION (KWH/T)

COMMINUTION: 0.8980E+01
AUXILIARIES: 0.7920E+01

TOTAL: 0.1690E+02 KWH/T

CUMULATIVE KWH/T OF FINISHED PRODUCTS

SPECIFIC CONSUMPTION FOR CRUSHING AND DRYING IS CALCULATED IN TWO PARTS. ELECTRICAL CONSUMPTION FOR DRYING IS CALCULATED USING THE COMBINED PRODUCTION RATE OF THE RAYMOND MILLS (41 T/H). THE RESULT IS THEN ADDED TO THE CONSUMPTION FOR PRIMARY CRUSHING.

CUMULATIVE SPECIFIC ENERGY INCLUDES CONSUMPTION FROM PRIMARY CRUSHING, DRYING AND MILLING OF GYPSUM. THE REPORTED ENERGY ALLOWS FOR A YIELD OF 89% AT CALCINATION SINCE MOST OF THE CHEMICALLY COMBINED WATER IN THE GYPSUM IS DRIVEN OFF.

SPECIFIC ENERGY IS NOT REPORTED FOR PRODUCTION OF GYPSUM BOARD SINCE QUANTITY OF BOARD IS EXPRESSED AS SURFACE AREA. HOWEVER IT WAS ESTIMATED THAT COMMINUTION CONSUMPTION REPRESENTS ABOUT 5% OF TOTAL EQUIVALENT THERMAL CONSUMPTION FOR BOARD PRODUCTION. THE MAJORITY OF THERMAL CONSUMPTION IS FOR DRYING OF THE BOARD AFTER FORMING.

PRODUCT	COMMINUTION	AUXILIARIES	TOTAL
PLASTER	0.1030E+02	0.1030E+02	0.2060E+02

PHASE II - REQUIREMENTS (as defined by CANMET)

Establishment of Monitoring Methodology

A laboratory evaluation of commercially available and experimental instruments and monitoring techniques and systems potentially applicable to real-time monitoring of fine particles in grinding circuits shall be made and either existing equipment shall be selected or modified or new equipment shall be developed for subsequent pilot plant studies or real-time circuit control. It shall also be required to develop a sound sampling strategy and ensure good execution.

The preparation of a detailed technical proposal and cost breakdown for the Phase III work is to be provided as part of this requirement. A preliminary description of the third phase is included below.

Development of Pilot Plant Systems (Description Only)

A pilot closed circuit grinding system would be set up reflecting the best available state-of-the-art technology with respect to the needs of representative industrial minerals comminution. The plant would be instrumented for direct energy measurements and designed to allow modular introduction of experimental control systems and removal of material at various stages of comminution. Selected mineral products would be ground in the circuit with a record of total energy-audit versus operating characteristics being established for each. Monitoring/control systems to optimize the total energy consumption would be developed along with necessary software and hardware for their ultimate introduction into full scale plants. In essence, the pilot plant would become a "test-bed" for evaluating grinding control systems and procedures. Direct energy consumption would be immediately measured by instrumentation, indirect energy consumption would be measured or estimated off-line in parallel experiments related directly to the needs of the product user.

Introduction

The advantages of on-line control of milling circuits has been pointed out in a number of articles[1-4]. This interest in automatic control has given rise to development of a range of different types of equipment for on-line particle size measurement.

Davies[1] has identified 21 classes of equipment, classed on the basis of the principles used to sense and size the particles. This article, and earlier reviews[5] by the same author, describe the equipment in some detail.

Principles used to sense and size particles
1. Image replication and analysis
2. Electrical resistance change
3. Light scattering
4. Light obscuration
5. Light diffraction
6. Optical grating method
7. Beta-ray attentuation
8. X-ray absorption and fluorescence
9. Acoustic interference
10. Ultrasonic attenuation
11. Differential air classification
12. Hydroclone separation
13. Pulsating gas flow
14. Pressure drop in a nozzle
15. Transient and evaporative cooling of a hot wire
16. Impact and momentum measurement
17. Magnetic flux variations
18. Electrostatic ion capture
19. Glow discharge perturbation
20. Automatic sieve methods
21. Correlation techniques

Most of the instruments listed are either not directly applicable to the industrial mineral sector or not sufficiently proven to be regarded as commercially available. Thus, in order to focus the study, we investigated the status of on-line equipment development in North America and Europe. From this investigation, it was decided to direct attention to equipment based on light scattering and diffraction.

In addition, it was decided to study the status of automatic Blaine meters, which give a measurement of specific surface area rather than particle size, but could be used in control of mill circuits, particularly in cement plants.

As representative of light scattering equipment, the Microtrac, marketed by the Leeds and Northrup Company, was chosen because of its degree of development and commercialization in North America.

The Microtrac was evaluated under laboratory conditions. Its accuracy and repeatability were compared to the Sedigraph,* an instrument whose operating characteristics have been established over a long period.

No laboratory evaluation was made of automatic sampling equipment because a range of different types of samplers are commercially available and have been proven under plant conditions.

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* The Sedigraph 5000 is manufactured by Micromeritics Inc., Norcross, Georgia. It employs the sedimentation principle, with particles settling in a proprietary liquid and a beam of x-rays as detector.

Laboratory Comparison of Laser and Sedimentation Particle Size Analysis

The comparison of the two types of instruments was based on cement samples of which the 45 μm size had been determined by wet sieving, and other materials from the comminution study. The 45 μm size has been used as a quality parameter in the cement industry for many years. It has been accurately defined by the industry and by the U.S. National Bureau of Standards using electroformed micromesh sieves and, therefore, is a good reference point for establishing the accuracy of the Microtrac and Sedigraph.

The Microtrac can be used for wet or dry samples but, because of difficulties experienced in getting the dry sampling system to operate satisfactorily and concern about agglomeration of particles in the air stream, the comparison between the two instruments was carried out on slurried samples. Water, with a small quantity of detergent, was used as the dispersing medium for Microtrac samples. A proprietary liquid, Sedisperse A13, was used with the Sedigraph.

Sedigraph

Repeatability

To evaluate the repeatability of the Sedigraph, tests were made on a Portland cement from C.E.R.I.L.H.*, the research centre of the French cement industry.

Results obtained with the French cement are shown in the table overleaf. The particle sizes in the table are chosen to coincide with those detected by the Microtrac.

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* Centre d'Études & de Recherches de l'Industrie des Liants Hydrauliques.

Sedigraph - C.E.R.I.L.H. Standard Cement

Cumulative % finer than size shown.

µm	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Avg.	Mean Deviation*	Range
88	96.5	98.0	97.0	97.0	97.0	98.5	97.3	0.60	2.0
62	93.0	94.0	93.5	91.5	91.0	94.0	92.8	1.07	3.0
44	85.5	85.0	85.5	83.0	81.5	85.5	84.3	1.40	4.0
31	71.5	71.5	71.5	70.5	69.0	73.5	71.3	0.98	4.5
22	60.0	57.0	57.5	56.5	55.5	60.0	57.7	1.43	4.5
16	45.5	44.5	45.0	45.0	44.5	47.0	45.3	0.68	2.5
11	33.5	33.0	33.0	33.5	33.0	36.0	33.7	0.80	3.0
7.8	24.5	23.5	24.0	24.5	24.5	26.5	24.6	0.65	3.0
5.5	17.5	16.5	17.0	18.0	18.0	19.5	17.8	0.75	3.0
3.9	12.5	11.5	11.5	13.0	13.5	14.5	12.8	0.92	3.0
2.8	8.5	7.5	7.0	9.0	9.5	10.0	8.6	0.92	3.0

Each test result is an average of six readings.
* Measure of dispersion.

Accuracy

The accuracy of the Sedigraph was determined from results obtained on a C.E.R.I.L.H. cement which is used as a standard for particle size analysis.

The results are given below.

Sedigraph - C.E.R.I.L.H. Cement

Cumulative % finer than size shown.

µm	Mean Sedigraph Value (%)	Assigned Value (%)
88	97.3	94.5
62	92.8	89.5
44	84.3	82.0
31	71.3	70.0
22	57.7	57.0
16	45.3	44.5
11	33.7	35.0
7.8	24.6	25.5
5.5	17.8	20.0
3.9	12.8	14.0
2.8	8.6	9.5

A further evaluation of Sedigraph accuracy was made from the 45 μm (#325 mesh fineness) determination on the six Portland cements. The #325 mesh fineness had been determined by wet sieving at ten separate laboratories as part of a Canada Cement Lafarge inter-laboratory program. Sedigraph and #325 mesh results are compared in the following table.

Wet Sieving v. Sedigraph at 45um

Sample No.	#325 (45μm) % Passing	Sedigraph % finer than 45μm
240	94.3	95.2
241	98.1	98.0
277	94.9	94.1
281	86.3	85.8
287	91.1	90.0
294	95.3	95.1

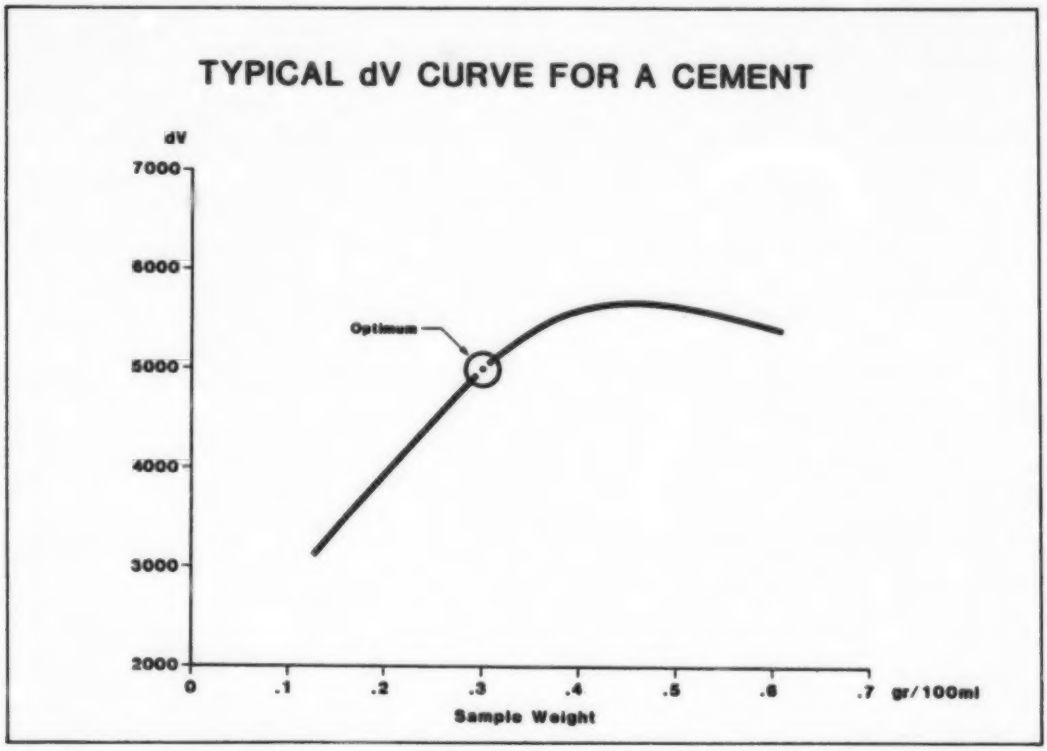
It is concluded from the results that, over the particle size range under study, the Sedigraph has both good accuracy and repeatability.

Microtrac

The Microtrac results are influenced by the weight of sample (as opposed to the Sedigraph which is relatively insensitive to sample weight). The manufacturer stresses the importance of the optimum weight of sample, and the instrument is equipped to indicate this optimum in the form of a number called "dV".

The dV number is defined as "a volume response giving an uncalibrated indication of the amount of particulate matter in the system". With the Microtrac, it is important that sample loading be low enough to keep main-beam attenuation and multiple light scattering at non-critical levels but high enough to achieve good resolution at the diffraction angles involved.

Optimum sample loading is obtained by plotting the dV number against variations in sample weight. The recommended sample weight is that near the peak of the resulting curve. A typical dV curve is shown in the figure below.



Results of dV and optimum loading weights for the six test Portland cements are given below. Densities for Portland cements are constant at 3.15 g/cm^3.

Optimum Loading and dV for Portland Cements

Sample No.	Surface Area Blaine (cm^2/g)	dV	Optimum Sample Weight (g)
240	5490	.2396	0.15
241	5290	.2483	0.15
277	4500	.4006	0.25
281	2980	.5645	0.30
287	3420	.4518	0.30
294	4010	.3794	0.25

The results indicate that dV and optimum loading weights vary in relation to the surface area of the material in spite of a constant density.

Optimizing the dV response of the Microtrac will be an important parameter in any on-line application where wide ranges of fineness could be found.

Repeatability

Repeatability of the Microtrac for the analysis of a standard cement is demonstrated in the next table, which shows that the variation in Microtrac results is similar to the Sedigraph for the standard cement.

Microtrac - C.E.R.I.L.H. Standard Cement

Cumulative % finer than size shown.

µm	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Avg.	Mean Deviation*	Range
88	100	100	100	100	100	100	100	0.00	0.0
62	98.1	100	99.4	100	99.8	100	99.6	0.52	1.9
44	94.7	98.1	95.8	96.5	96.2	96.7	96.3	0.77	3.4
31	85.7	87.1	87.5	86.1	87.0	85.8	86.5	0.67	1.8
22	71.1	71.0	73.4	72.6	72.0	73.0	72.2	0.82	2.4
16	57.0	58.9	59.1	58.4	58.0	58.3	58.3	0.52	2.1
11	41.2	42.6	42.1	42.2	42.6	42.0	42.1	0.35	1.4
7.8	28.5	29.1	29.9	29.3	28.0	29.5	29.1	0.52	1.9
5.5	17.1	18.4	20.4	18.7	17.6	19.3	18.6	0.88	3.3
3.9	8.6	9.5	10.5	9.8	9.3	10.4	9.7	0.55	1.9
2.8	4.4	4.7	4.4	4.1	4.3	3.9	4.3	0.20	0.8

Each test result is an average of six readings.
* Measure of dispersion.

Accuracy

The Microtrac results for the standard C.E.R.I.L.H. cement are compared with the assigned values in the following table.

Microtrac - C.E.R.I.L.H. Standard

Cumulative % finer than size shown.

Particle Size (μm)	Mean Microtrac Value (%)	Assigned Value (%)
88	100	94.5
62	99.6	89.5
44	96.3	82.0
31	86.5	70.0
22	72.2	57.0
16	58.3	44.5
11	42.1	35.0
7.8	29.1	25.5
5.5	18.6	20.0
3.9	9.7	14.0
2.8	4.3	9.5

The Microtrac results are considerably higher than the assigned values from 88 to 7.8 μm. Below this particle size, the results are lower than assigned values.

An estimation of Microtrac accuracy was also made by evaluating its performance at the 45 μm size. The following table, comparing wet sieving, Sedigraph and Microtrac results for the six test cements, confirms that the Sedigraph is more accurate for this particle size.

Wet Sieving v. Microtrac at 45 μm

Sample No.	No. 325 (45 μm) % Passing	Microtrac % Finer Than 45 μm
240	94.3	100.0
241	98.1	98.8
277	94.9	97.0
281	86.3	87.5
287	91.1	97.2
294	95.3	94.8

On the average, Microtrac results are consistently higher than those of wet sieving, but not to the extent seen with the standard cement.

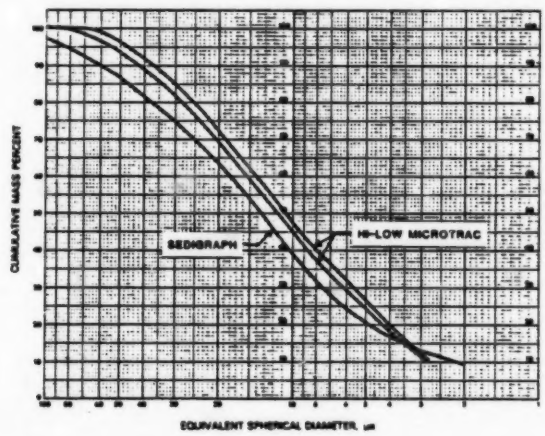
Particle size analysis of non-cement materials

A comparison of the results from the Microtrac and Sedigraph analysis of the following materials

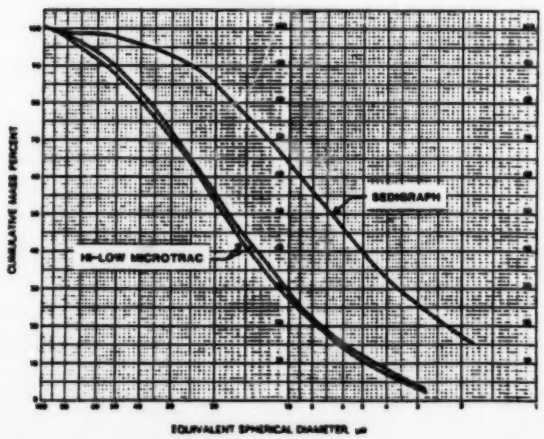
- cement raw mix
- mica
- limestone, limestone (calcite)
- talc
- nepheline syenite

are shown in the graphs below. The "hi-low" Microtrac curves give the range of results obtained from a set of samples.

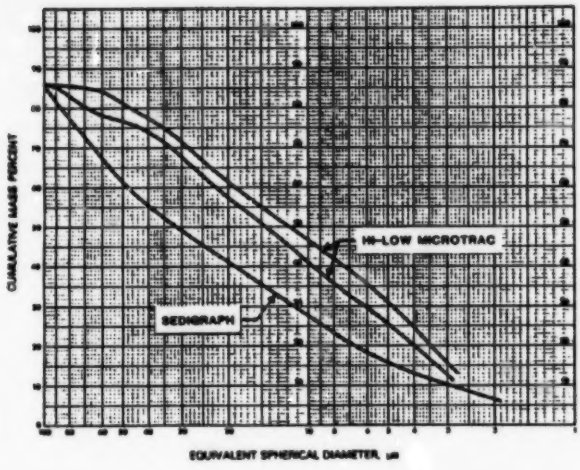
CEMENT RAW MIX



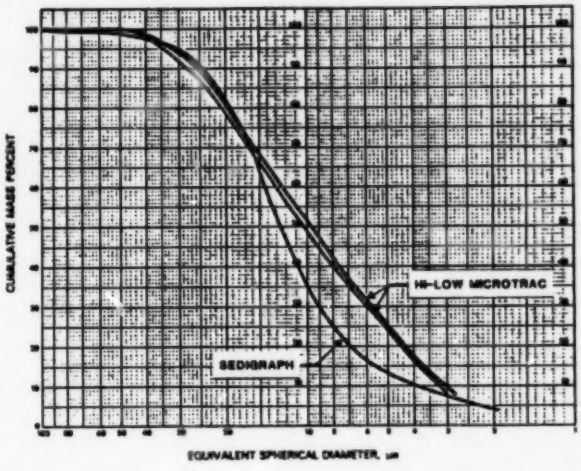
MICA



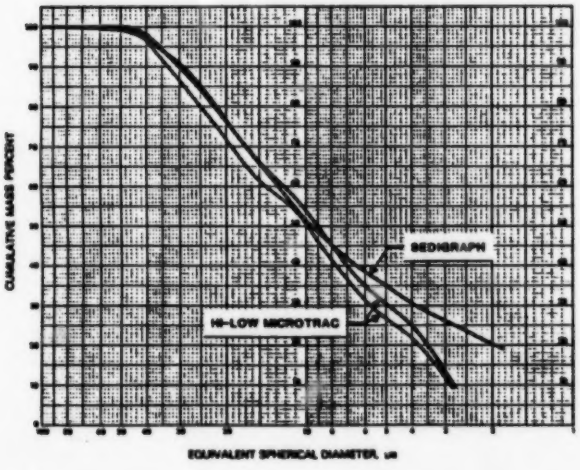
LIMESTONE



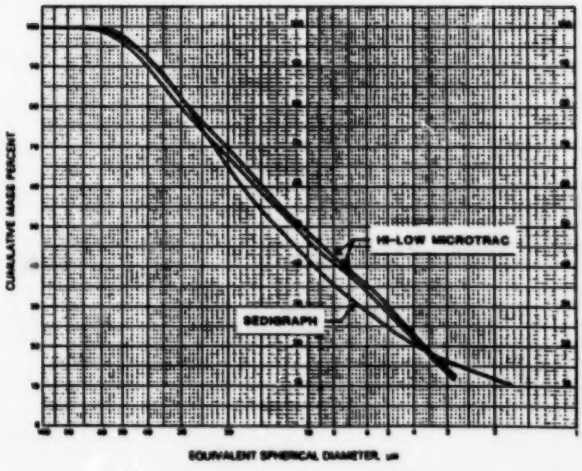
TALC



LIMESTONE - (Calcite)



NEPHELINE SYENITE



For the Portland cement raw mix, composed of a mixture of limestone and shale, No. 325 wet sieving indicated 81.2% passing at 45 μm. The Sedigraph and Microtrac gave 83.8% and 93.0%, respectively. This result is consistent with earlier data indicating that the latter is less accurate at the coarse end of the scale.

The results for the mica sample show the largest difference between the two instruments. The wide difference in results could be attributed to the shape of the particles affecting sedimentation.

There is also considerable difference in results for the Domtar limestone sample. Differences like this are difficult to explain without further exploration, but could be due to poor dispersion in water of the Microtrac samples.

In general, the reproducibility of the Microtrac results for the industrial minerals was found to be within the ±5% range quoted by Leeds and Northrup[9].

On-line Application of Particle Size Analysers

On-line applications of a number of types of particle size analysers are summarized in the table below.

ON-LINE APPLICATIONS			
CLASSIFICATION BASED ON PARTICULATES CONCENTRATION IN THE SENSING REGION	MODE		CURRENT STATUS
	WET	DRY	
I. Low Concentration Methods (single particles)			
- Electrical Conductivity	X		- Restricted to contaminants.
II. High Concentration Methods (5-70% by weight)			
- Hydrocyclone	X		- Tested in plant environment[6].
- Automatic Sieving	X		- Not in current use. Min. 100 um particles.
- Ultrasonic Attentuation	X		- Tested in plant environment[6] (Armco Autometrics).
- Beta-Ray Attentuation	X		- Not in use.
III. Intermediate Concentration Methods (0.1% by weight)			
- Light Diffraction		X	- Cilas; not in current use.
	X	X	- Microtrac: currently installed in a number of locations.
- Differential Air Flow		X	- Metzger & Leschonski's Model: commercialization in process[8].
IV. Air Permeability (Blaine meter)		X	- Japanese development - unknown; presumed abandoned
		X	- Fuller's mid 70's model: abandoned.
		X	- Milltronic's early 70's model: abandoned.
		X	- Holder Bank - Hasler: currently in plant testing.

The first category is applicable to low concentrations of particles and not directly relevant to industrial mill circuits. The high concentration methods were not explored further because they do not appear to be under active development at present.

Of the remaining two categories, laser systems have been tested under plant conditions, a differential air flow method is reported to be ready for commercialization and at least two automatic Blaine meters are installed in plants.

Laser Systems

The Microtrac is the most widely commercialized particle size analyser in this category. In North America, some 400 units are reported to have been sold to a wide range of industries, including explosives, food, chemicals, minerals and oil.

A number of industries, where on-line monitors are installed, were contacted. The applications are shown in the table.

ON-LINE MICROTRAC APPLICATIONS

INDUSTRIES	PLANT & LOCATION	PARTICLE CHARACTER-ISTICS	MODE	
			WET	DRY
Cement	- Calavares Cement Redding, California, USA	80-90% passing 325 mesh		X
	- Florida Mining Brooksville, Florida, USA			X
	- Lonestar Cement Seattle, Washington, USA			X
	- Blue Circle Industries Greenhithe, Kent, UK			X
Talc	- Talc-de-Luzenac Luzenac - Ariège, France	10-50 µm		X
Minerals (Tailings)	- Lornex Mining Logan Lake, B.C., Canada	2.7-300 µm	X	
Alumina	- Alcoa Tech. Centre Alcoa Centre, Pa, USA	--	-	-
Iron Ore	- Iron Ore Company Newfoundland, Canada	65% passing 44 mesh	X	
	- Bethlehem Steel Bethlehem, Pa, USA	--	X	

The results from the talc and iron ore plants were reported to be satisfactory, while the cement industry and mine tailings still had problems to overcome. The main difficulties cited for the dry mode were control and presentation of the sample in a dispersed form to the laser beam. In the wet mode, daily clean-up of the sample cell was necessary and abrasion was a problem. Very little quantitative data describing the performance of the instruments was available.

In general, some concern was expressed about the ability of the instrument to stand up to the heat, dust and vibration in a plant environment.

Permeability Systems (Blaine meter)

Hasler Frères SA have developed an automatic Blaine meter. One of these meters has been installed at a German cement plant since 1982 and is, according to a Hasler report[10], operating well.

The objectives of the installation were;

1) to insure a constant fineness of the finished cement within a divergence of ± 100 for three different Blaines (3100 - 4300 - 4900 cm^2/g);

2) to have maximum possible output at these finenesses;

3) to reduce the energy consumption of the mill to the minimum;

4) to be adjusted easily to different types of input material;

5) to enable the system to be controlled remotely.

The mill being controlled has two compartments, a 3500 hp motor and an output of about 100 t/h. It is equipped with a Pfeiffer Turbo separator.

Ciments Lafarge France commissioned a Hasler automatic Blaine meter, at a cement plant in Marseilles, in early 1983. No reports on the performance of the equipment are available yet.

The Sedigraph is an accurate instrument, giving good reproducibility of results in the 100 - 2 μm range. Because of the time required to prepare and run samples, it is best suited for a laboratory role. However, it provides a useful reference for evaluating the performance of other instruments.

Laser based instruments of which the Microtrac is the most developed and commercialized in North America, could be used for on-line particle size analysis in the industrial minerals industry, if the problems associated with dispersing the particles and presenting a dry sample of suitable concentration to the sensor can be overcome.

The reproducibility of the Microtrac results is similar to the Sedigraph, but generally gives higher readings.

It can span a wider range of particle sizes, 200 - 2 μm, compared to 100 - 2 μm.

The Microtrac scanning time can be as low as 25 seconds, compared to 25 minutes for the Sedigraph.

The Microtrac has apparently been tried in a number of on-line applications but with limited success.

Automatic Blaine meters are installed in at least two cement plants in Europe. One is reported to have performed satisfactorily since 1982. The other was commissioned in 1984.

The Blaine meter gives a measure of specific surface area rather than particle size and has a slower response time than the Microtrac but could be used for mill circuit control, particularly in the cement industry.

The task, as originally defined, specified that a detailed technical proposal and cost breakdown for a pilot plant be prepared. However, there are a number of well-equipped R&D organizations in Canada with suitable pilot plant facilities and extensive experience in mineral processing. Therefore, we believe that it would be more economical to conduct a test program in existing facilities, rather than constructing a new pilot plant.

Proposed Test Program

The test program should be designed to integrate the recommendations from this study with the findings of the CANMET survey of opportunities and problem areas in the industrial minerals industry. A report on the survey was published in 1983.*

A summary of the survey results and study recommendations for each of the minerals is shown in the table below and continued overleaf. The survey results apply to overall processing, while the study recommendations are comminution related.

Mineral	Processing Problem Areas Identified in Survey	Comminution Study Recommendations
Asbestos	- Improved screening of damp fibre. - Improved and more efficient separation of fibre at 75 µm. - Separation of mica from asbestos fibre. - Development of techniques for filtering and drying fibre without degradation. - Improved techniques for characterizing and evaluation of fibre. - Development of wet treatment processes for fibre recovery. - Improved screening capacity and life of screens by use of rubber-covered screen grids. - Tendency of damp fibre to adhere to processing equipment. - Improved filtration for asbestos-cement systems.	Develop wet milling technology in order to reduce the power consumed in dust collection in dry milling.
Cement	- Improved crushing of raw limestone to produce finer size material as feed to raw milling circuit. - Grinding of slag cements.	Improve the classification of cement to reduce the amount of coarse and superfine material in the finished product. This represents an opportunity for Canadian manufacturers to develop new equipment or find ways of retrofitting existing classifiers. Test the efficiency of other dry milling systems, for example, tower mills, for grinding clinker.

* R.K. Collings & P.R.A. Andrews, CANMET, Report 83-SE.

Mineral	Processing Problem Areas Identified in Survey	Comminution Study Recommendations
Gypsum	- Blasting, crushing, grinding to minimize fines production (minus 10 mm). - Gypsum/anhydrite middling product in heavy media processes. - Crushing of gypsum; although the rock is not hard or abrasive, it is more difficult to crush than many harder rocks; crusher types, sizes. - Study on pelletizing of fines. - Process monitoring and control.	No specific recommendations.
Lime	None reported.	No specific recommendations.
Limestone (Calcite)	- The removal of impurities, e.g., iron and magnesium silicates, by colour sorting, magnetic separation, etc., to enable production of higher grade material for fillers, cosmetics, and pharmaceutical applications.	No specific recommendations.
Mica	- Beneficiation, applicability of magnetic separation, gravity separation, leaching, flotation and air classification. - Mica grinding and delamination to produce a higher aspect ratio flake for use as reinforcing agent in plastics. - Delamination and breakage of ultra-thin flakes in the mixing/dispersion/coupling process. - Classification of mica. - Feasibility of the recovery of quartz, kyanite, staurolite and associated minerals as co-products from Ontario mica deposits.	Test alternative milling systems for delaminating and grinding mica with a view to reduction of the power consumed in the manufacture of fine mica products.
Nepheline Syenite	- Reduction of Fe_2O_3 in hornblende nepheline syenite. - Development of methods of ultra-fine classification, especially in 16 μm range.	Test the efficiency of autogenous milling to reduce the number of comminution stages.
Potash	- Development of dry methods for potash recovery, e.g., electrostatic separation. - Potash flotation; computer control in flotation circuits. - Compaction of potash fines. - Recovery of KCl salts by brine evaporation. - Development of instruments to analyze for KCl. - Loss of potash values to waste salt.	No specific recommendations.
Silica	- Grinding and classification of sandstone, especially tertiary grinding to achieve more effective reduction of sandstone to natural grain size without grain fracture and overproduction of fines. - Beneficiation of sand to glass-sand purity, especially dry beneficiation processes for removal of pyrite and shale. - Reduction of iron in silica sand to 0.005% Fe_2O_3 for optical glass. - Reduction of iron in silica fines to "chemical" standards. - Production of ultra-high purity silica/silicon for silicon chip manufacture. - Reduction of quartzite/sandstone to free impurities; removal of impurities followed by agglomeration for specialty, high-purity uses, e.g., silicon production (probably too costly in view of relatively low price for high purity, lump silica). - Excessive wear on crushing and grinding equipment.	Explore ways of producing a ground silica with rounded grains suitable for foundry use to replace imports.
Talc	- Beneficiation: magnetic separation, gravity concentration, leaching, flotation, air classification. - Removal of iron, chlorite, and dark mineral particles to upgrade and improve brightness of product. - Grinding, particularly wet pebble mill grinding, prior to flotation. - Fine grinding and delamination to 90% minus 5 μm for use in filler applications.	Investigate the use of pebble mills as a more efficient means of grinding superfine products.

So that the pilot plant addresses as far as possible the major issues raised by the survey and the current study, we recommend that the test program be selected from the following topics:

asbestos	- investigate wet milling;
cement	- improve classification,
	- investigate the efficiency of alternative types of mills for clinker grinding;
gypsum	- investigate crushing;
mica	- test alternative milling systems to produce a higher aspect ratio flake and reduce power consumption;
silica	- explore ways of producing a ground silica suitable for foundry use;
talc	- investigate alternative mills (for example, pebble mills) as a more efficient means of producing superfine products;
grinding aids	- investigate the nature of the bonding forces in particle agglomerates and the effectiveness of commercial grinding aids in dispersing the agglomerates;
crushing and milling	- since crushing requires less energy than grinding, seek ways to optimize mill feed preparation in crushing circuits;

particle size monitoring - test the performance of laser particle size monitors and automatic Blaine meters under pilot plant conditions;

circuit control - develop mill circuit control strategies using on-line particle size monitors.

It is recommended that criteria be developed to rank these topics by order of importance, so that a schedule for the pilot plant test program be established.

Cost Estimates

Based upon an estimated cost range of between $25,000 to $35,000 per month for pilot plant testing, the graph on the following page indicates the "available Pilot Plant Months" for a particular budget.

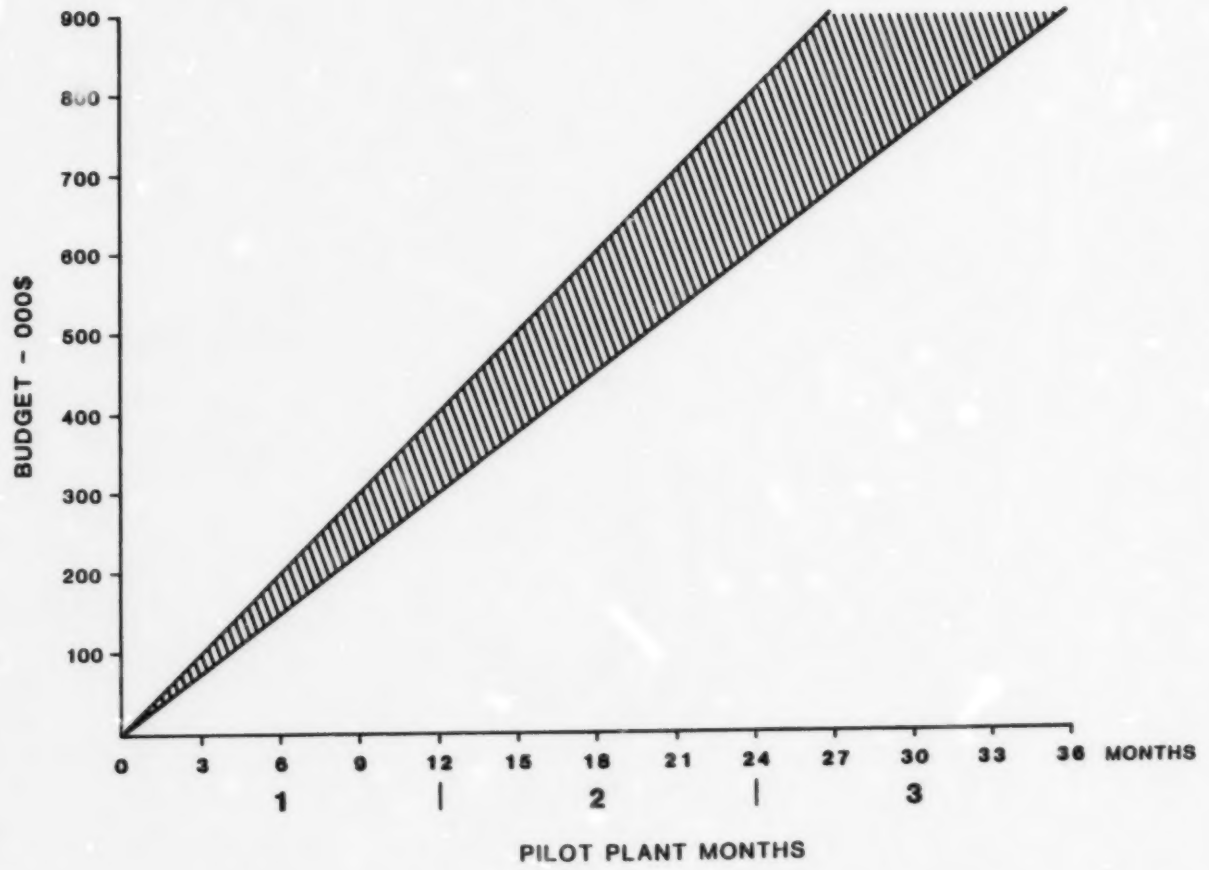
Programs will vary in length as well as importance and, in many cases, be extended. The graph, therefore, provides a source of quick reference to determine funds necessary to cover estimated costs.

As shown, a budget of between $300,000 to $425,000 will be required for the first year, depending on the type and nature of programs scheduled.

Subsequent years can be tailored to conform to available funds.

PILOT PLANT AVAILABILITY GRAPH

$25,000-$35,000 / MONTH COST



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